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SUMMARY OF RESEARCH 1996

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This report contains summaries of research projects in the Department of Mechanical Engineering. A list of recent publications is also included which consists of conference presentations and publications, books, contributions to books, published journal papers, technical reports, and thesis abstracts.

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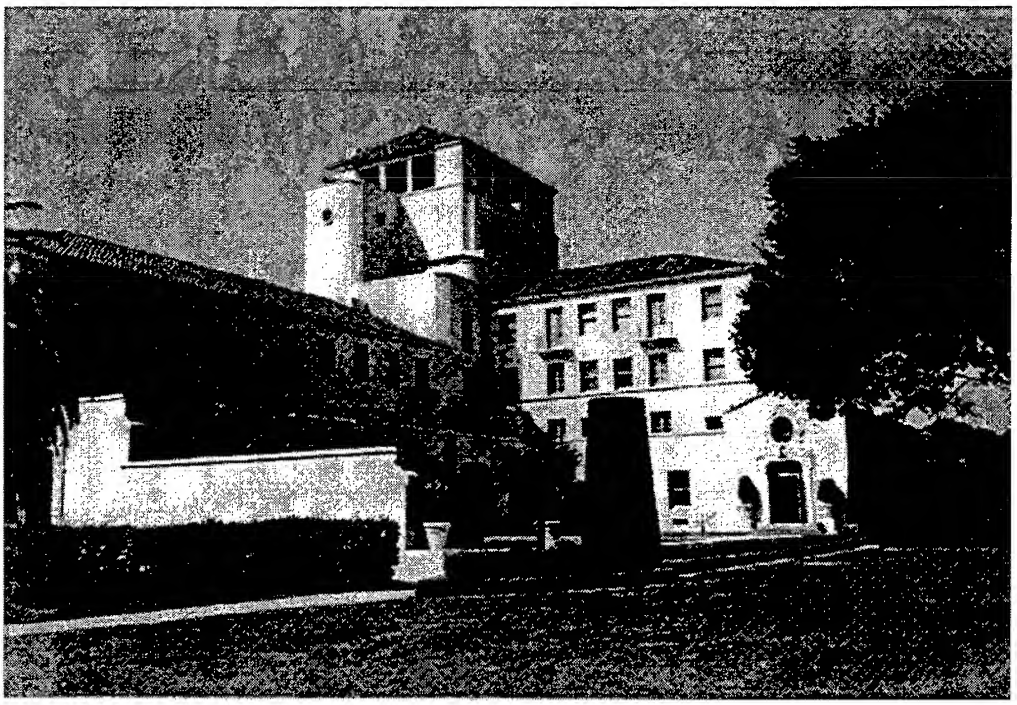
DEPARTMENT OF MECHANICAL ENGINEERING

TERRY MCNELLEY
CHAIR

THE NAVAL POSTGRADUATE SCHOOL MISSION

The mission of the Naval Postgraduate School is to increase the combat effectiveness of US and Allied armed forces and enhance the security of the USA through advanced education and research programs focused on the technical, analytical, and managerial tools needed to confront defense-related challenges.



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Preface

Research is an integral part of graduate education. At the Naval Postgraduate School (NPS), the goals of research are to:

- Provide a meaningful, high quality, capstone learning experience for our students.
- Keep faculty on the leading edge of advances in defense-related science, technology, management and policy to ensure that the latest information is incorporated into NPS courses and curricula.
- Apply faculty and student knowledge to enhance DoN/DoD operational effectiveness.

Pursuit of these goals increases the technical and managerial capability of the officer corps to keep pace with an increasingly complex defense posture in today's world.

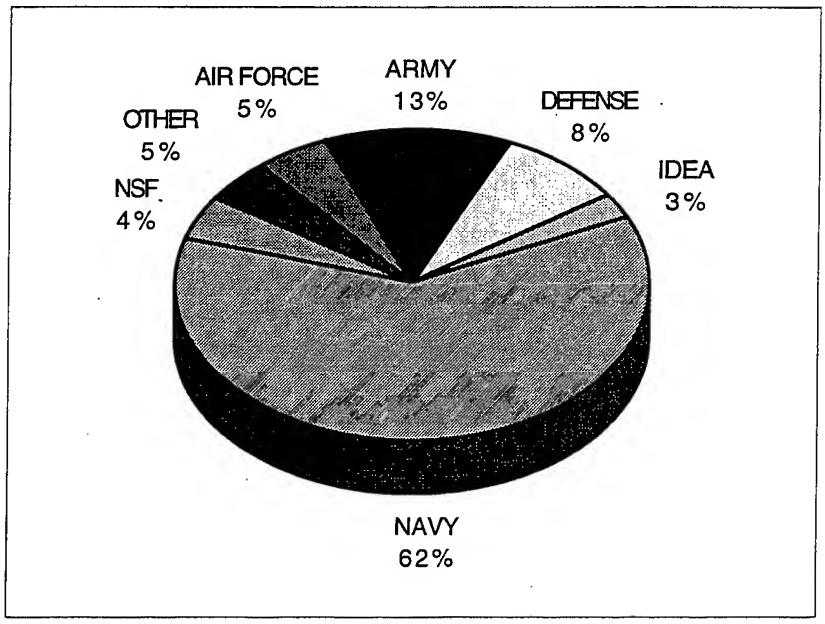
New technologies and policy changes will of course occur, necessitating changes in educational programs and stronger ties between the fleet and the support establishment. NPS must remain poised to face this challenge and to utilize emerging technologies and new policies within its curricula programs. Faculty, therefore, must stay abreast of these developments through a dynamic research program that helps fulfill the School's goals of excellence, uniqueness, and relevance.

The overall research program at NPS has three funded components. The Direct Funded Research and Institute for Joint Warfare Analysis Programs are institutionally funded within the School's operating budget. The Direct Funded Research Program is administered by the Associate Provost and Dean of Research. The Institute for Joint Warfare Analysis Program is administered by the Director of IJWA.

- The Direct Funded Research (DFR) Program provides funding to stimulate innovative research ideas of benefit to the DoN and may be used for cost-sharing with reimbursable research efforts. This funding ensures, in particular, that all Navy-sponsored NPS curricula are equitably supported, that new faculty are provided an opportunity to establish a research program of importance to DoN/DoD and other national security interests, and that faculty and students from across the campus are encouraged to interact with one another.
- The Institute for Joint Warfare Analysis Research Program provides funding to stimulate innovative research ideas with a strong emphasis on joint, interdisciplinary areas. This funding ensures that joint relevance is a consideration of faculty research.
- The Reimbursable Research (RR) Program includes those projects externally funded on the basis of proposals submitted to outside sponsors by the School's faculty. These funds allow the faculty to interact closely with RDT&E program managers and high-level policy makers throughout the Navy, DoD, and other government agencies as well as with the private sector in defense-related technologies. This ensures that NPS research remains highly regarded by academic peers and government officials and fosters a closer relationship between NPS and other outside organizations.

The three research programs are complementary and ensure that the overall research program is flexible, responsive, balanced and supportive of the unique needs of the military.

In 1996, the level of the research effort at the Naval Postgraduate School was 141 faculty workyears and exceeded 29 million dollars. Eighty percent of the research was funded by reimbursable sponsors and 20 percent was funded by the Naval Postgraduate School. Sixty-five percent of the work was performed for the Navy and the remainder was sponsored by other agencies, both DoD and non-DoD. A profile of the reimbursable program of the Department of Mechanical Engineering is provided in Figure 1:



Size of Program: $1,269K

Figure 1. Department of Mechanical Engineering - Sponsor Profile

Research at NPS is carried out by faculty in the School's eleven Academic Departments, four Interdisciplinary Groups and the School of Aviation Safety. In the pages that follow, research summaries are provided for projects undertaken by faculty in the Department of Mechanical Engineering during 1996. An overview and faculty listing are provided as an introduction. A list of publications is also included, if applicable. Abstracts for thesis advised by department faculty in 1996 complete this research summary.

Questions about particular projects may be directed to the Faculty Principal Investigator listed, the Department/ Group Chair, or the Department Associate Chair for Research. Questions may also be directed to the Research Office. General questions about the NPS Research Program should be directed to the Research Office at (408) 656-2098 (voice) or research@nps.navy.mil (e-mail).

August 1997

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DEPARTMENT SUMMARY

The Department of Mechanical Engineering's research effort comprises activities in five main areas: the thermal/fluid sciences; solid mechanics and vibration; dynamic systems and controls; material sciences; and total ship systems engineering. Individual programs of relevance of Navy continue to advance the state of knowledge in each of these areas. Results of these research programs are published in student theses, NPS technical reports, in technical papers given at various national and international conferences, and are also published in a wide variety of scientific journals.. The individual programs associated with each faculty member are described in the following overviews, which correspond with the main discipline areas of the Department.

Fluid Dynamics, Heat Transfer and Turbomachinery

Turgut Sarpkaya, Distinguished Professor: A series of new experiments have been designed to understand the influence of several competing internal/external influences such as turbulence, gravity, surface tension, liquid-sheet geometry, surface shear, roughness of the contact surfaces, velocity distribution in the sheet, and pressure fluctuations within and outside the sheet to understand, model and predict droplet and spray formation. The technological importance (IR signatures) and intellectual challenges (stability of a two phase flow) presented by this nontrivial flow phenomena demand a scientific understanding of its physics through judiciously conceived physical experiments and numerical analyses which are now underway with the support of ONR.

Secondly, a combined analytical, numerical, physical, and thought experiments were undertaken to address the old and difficult problem of devising a physics-based model for the prediction of flow-induced unsteady forces on bluff bodies immersed in time-dependent flows. The new model, based on a sounder scientific rational, is expected to replace Morison's equation and offer greater universality and higher engineering reliability, particularly in the so-called drag-inertia regime. The project is supported by ONR.

Thirdly, the statistical as well as structural characteristics of the turbulent flow field resulting from the interaction of a *turbulent jet* with clean and contaminated free surfaces were investigated in order to elucidate the physics of the phenomena relevant to the understanding of near-surface structures in ship-generated wakes. It has been shown that the predominant coherent structures are small vortices whose preferential merging leads to reverse energy cascade and eddy longevity. The entire process is driven by the underlying, nearly isotropic, three-dimensional turbulence field and is of special importance towards the understanding and interpretation of surface signatures generated by ships and submerged bodies. The project is supported by ONR and NPS.

Finally, a basic and applied research was undertaken towards the understanding of the phenomena resulting from the breakdown of vortices in trailing vortices and in a turbulent flow field, created by a round swirling jet issuing from a nozzle. The ultimate purpose of the investigation is to quantify the phenomena leading to the rise and demise of trailing vortices and to find means to alleviate the wake-encounter-hazard problem with the support of NASA.

Ashok Gopinath, Assistant Professor: Professor Gopinath has been conducting research in "Convective Heat Transfer induced by Strong Acoustic Fields" as part of an ongoing program towards improving heat exchanger design in thermoacoustic engines. The goal is to obtain a better understanding and quantify the heat transfer behavior in strong zero-mean internal oscillatory flows. A considerable amount of data has been gathered using a basic experimental rig and various test sizes of a cylinder which is representative of a heat exchanger tube. Useful working correlations have been developed for predicting the heat transfer behavior and much insight has been gained into the behavior of fluid and heat transport in such internal oscillatory flows.

Also, during CY-96, a project was completed for the U.S. Coast Guard which explored the cost-saving option of replacing steam with hot-water aboard Coast Guard cutters for compartment heating applications. A detailed analysis of typical heat exchange systems aboard these cutters was conducted which accounted for various configurations and flow rates. It was recommended that with a minimal sacrifice in the heat delivery, hot water based hydronic systems can indeed be used in place of the more expensive and trouble-prone steam based systems currently being used, without a major overhaul in the existing heat exchange equipment.

Finally two new projects were initiated in FY97 (10/96) under the auspices of the NASA Microgravity Program. These projects deal with fundamental phenomena in thermoacoustics and hold promise for evolving into possible future flight experiments aboard the Space Shuttle.

Knox T. Millsaps, Assistant Professor: Methods to reduce lateral vibration of gas and steam turbine rotors have been developed using both analytical and experimental techniques. Using steady state and transient lumped parameter models and an experimental rotor facility, the impact of several parameters on rotordynamic response, including asymmetric bearing parameters and acceleration rates, have been investigated. Design rules for minimizing vibration amplitudes have been developed for steady state cases. Further work has extended these results to accelerating rotors. The results from both the model and the experiment confirm that it is possible to schedule acceleration of a rotor through critical speed, to minimize lateral deflections or total vibrational energy. Current research is focused on optimizing these acceleration schedules.

Methods for identifying and localizing faults in a real Diesel engine are being developed. Specifically, an engine cycle analyzer is being used to access various methods for identifying induced combustion faults and to localize them. Techniques based on high response instrumentation and advanced signal processing, such as Joint-Time-Frequency-Analysis (JTFA) are being applied to identify patterns which are characteristic of certain classes of faults. Determining the type of faults that can be detected and localized and the specific type of JTFA that is optimum for a given fault is the primary focus of the research. Adaptive JTFA has been able to localize fuel injection timing faults and assembly faults. A method for predicting in-cylinder firing pressure measurements based on instantaneous angular speed of the shaft has been developed and verification is underway.

Solid Mechanics, Shock and Vibration

Young S. Shin, Professor: Professor Shin has continued his investigation of "Response of Naval Structures to Underwater Explosion" under the sponsorship of the Naval Sea Systems Command (NAVSEA), and Naval Surface Warfare Center (NSWC)-Annapolis Detachment. For NAVSEA project, modeling and ship shock simulation of DDG-51 Flight I was conducted, and fluid-interaction and cavitation effects were studied. NSWC-Annapolis has been developing Advanced Lightweight Influence Sweep System(ALISS). Professor Shin has performed the shock and vibration analysis of _ scale GA superconductor magnet model to assess the survivability in severe environment. In addition, research is also being performed in: (1) the dynamics of underwater explosion gas bubble and its interaction with boundary surface using Lagrangian-Eulerian finite element analysis approach, (2) age-reliability analysis of shipboard repairable systems, (3) human survivability in ship shock environment, and (4) Survivability of tactical advanced computers in shock, noise and vibration environment.

Young W. Kwon, Associate Professor: Professor Kwon worked on four major projects during this reporting period. Three of them were sponsored projects and the other was unfunded. The first project funded by the Air Force Phillips Laboratory was to investigate damage/crack initiation in solid rocket propellants. In order to predict and understand the damage/cracking process, a numerical modeling and simulation technique was developed using the micro/macromechanical approach and damage mechanics. Using this technique, initial crack sizes and their cracking process could be well examined. Experimental data also validated the numerical technique. The second project was the biomechanical research sponsored by the Naval Medical Center and NPS. This project was a continuing research from previous years. This year's effort was placed on evaluating different testing methods used by other researchers and comparing them to the NPS testing method. Other testing methods required artificial constraining the cadaver while this testing did not require it. The results showed that artificial constraining did not yield proper knee kinematics. In addition, a mathematical formulation was developed to determine the axis of rotation of each knee motion using the measured data. The research attempted to correlate the axis of rotation to the motion of a bone landmark. This would help surgeons perform the knee surgery. The geometric modeling of the knee joint was also conducted for the following mathematical modeling of the knee joint.

The third project was a numerical study of thermomechanical processing of particle-reinforced metal-matrix composites. This was a collaborative work with Professor McNelley and sponsored by the Army Research Office. The research investigated the particle redistribution process in the metal matrix material during thermomechanical processing using the finite element method. The numerical model considered clusters-of-particles zones embedded in a coarse-grained matrix. The numerical simulation deformed the composite material up to true strain of 1.0 under cold-working and hot-working conditions. The study showed the deformation process of clusters-of-particles zones within the matrix, which qualitatively indicated the trend of particle redistribution in the metal-matrix composite. The last project

was related to the design optimization using the finite element analysis. Finite element analysis has been popular in engineering designs. The design process, especially for an optimum design, required a lot of design iterations which also required many finite element analyses. However, a finite element analysis is very time consuming and expensive for practical design problems. As a result, a simple and efficient optimal design technique was developed using the orthogonal array concept so that the number of finite element analyses could be minimized during the design cycle. As demonstration examples, the developed technique was applied to structural optimization problems with discrete and/or continuous design variables.

Joshua Gordis, Assistant Professor: Assistant Professor Joshua H. Gordis of the Department of Mechanical Engineering is conducting research in several areas in structural dynamics and vibration. In structural synthesis, a family of analytic methods have been developed which allow the direct calculation of modified dynamic response of structural dynamic system computer models which have been arbitrarily modified and/or combined with other models. These methods are distinguished by their ability to treat modifications of arbitrary size, distribution and damping, and that the methods provide a highly efficient and exact solution in all cases, where the synthesis is independent of model size. The time domain synthesis formulation is currently being extended to address local nonlinearities in large linear systems.

Research is also being performed in structural system identification, where deficiencies in math models are identified through the use of measured dynamic response data. Recent results here include the identification of an non-standard set of eigenvalues which provide a additional, independent data with which to tackle the underdetermined system identification problem. The system identification methods are being applied in the area of structural damage detection, which seeks to uncover structural damage in components using measured dynamic response data. Additional areas of research include the structural dynamic analysis of the Boeing-Sikorsky RAH-66 Comanche helicopter, the vibration testing of the McDonnell-Douglas OH-6 helicopter, and the optimal design of shock and vibration isolation systems.

Dynamic Systems, Controls and Robotics

Anthony H. Healey, Professor: Professor Healey was active in furthering the technology of Autonomous Underwater Vehicles and in land based robot systems for minefield and unexploded ordnance clearance. In particular, the *Center for Autonomous Underwater Vehicle Research* has formally been approved. Its facilities include the AUV laboratory in Building 230 housing a 20' by 20' 6' deep vehicle systems test tank that will support autonomous hovering maneuvers and high frequency imaging work of the AUV "Phoenix" a testbed vehicle designed and operated by the Center. In late 1996, a major advance was made towards performing the first autonomous mission in open water at the dock facility of the Monterey Bay Aquarium Research Institute. Major software developments were performed including the purchase and networked installation of a SUN Voyager notebook computer in the Phoenix vehicle. The AUV laboratory has been equipped with a radio ethernet connection to the NPS campus backbone and the vehicle computers are now installed as part of that network. This has facilitated rapid code development and file transfer so that student thesis work can be performed either on campus or at the Laboratory.

A major demonstration was performed during the Mine Countermeasures Conference hosted at NPS by a committee including Professor Healey,

International visitors to the Center included Professor Antonio Pascoal and his Ph.D., student Carlos Silvestri from the University of Lisbon in Portugal who have worked with Professor Healey in the development of Petri Net methodology for the discrete event control of AUV missions. Professor Pascoal is now spending his sabbatical year in the Center.

The effort is funded by the National Science Foundation, the Office of Naval Research, and the Naval Explosives Ordnance Disposal Technical Division.

Morris Driels, Professor: The project, Target Acquisition Model Evaluation; focused on the following models: The Acquire Search model, the IDA Search Model, the ORACLE Visual Performance Model, The NVESD Television Model, Acquire Version 1.0, FLIR92, and the NVESD Imaging Infrared Model. Appropriate software was obtained from the responsible agency, and each model was exercised over a wide range of input parameters to perform a basic sensitivity study, and determine appropriate bounds for the input parameters. Each model was evaluated according to

pre-specified criteria, and include a program description, computer requirements, associated models, applicable operational situations and included factors, model inputs and outputs, and model assessment.

A/S And S/S Target Acquisition Methodologies; is sponsored jointly by NPS, Naval Air Warfare Center-Weapons Division (NAWC), and the U.S. Army. The work involved the integration of three target acquisition and planning modules.

EOTDA, which is a weather/atmospherics program predicting target signatures as a function of location and time of day, TAPPS, which is a target masking prediction tool providing contours of clear line of sight around a target partially obscured by cultural features, and PVG, which is a high resolution terrain and feature rendering program for providing realistic imagery of the target area. Each part of the work was performed by the appropriate research group, with NPS handling the Perspective View Generator (PVG) part. Work to date has integrated the first two components in a PC-Windows environment, and the final integration and validation of the complete model will be conducted in FY97.

Fotis A. Papoulias, Associate Professor: Professor Papoulias conducted research on several aspects of maneuvering and depth control of submarines and submersible vehicles in the proximity of a free surface. Several studies were conducted in order to classify and evaluate various vehicle response characteristics. A systematic series of parametric studies revealed the dependence of the operability window of a vehicle in terms of its operating speed and depth, as a function of fundamental geometric quantities characteristic of the vehicle geometrical shape. These studies were conducted in all sea state and sea heading of interest. In addition to open loop dynamics, the closed loop control behavior of the vehicle was analyzed by utilizing a variety of control strategies. The results were tabulated in terms of the overall control accuracy. This provides a systematic way for analyzing the performance of the control system, and establishes rational guidelines for sensor selection. Finally, an experimental program utilizing parametric studies and the use of the NPS autonomous underwater vehicle as a test-bed was developed and proposed.

In addition, Professor Papoulias performed a preliminary analysis of roll stabilization schemes for a given class of surface ships to be used as mobile radar platforms. A careful analysis of the advantages and disadvantages of each system, in conjunction with the ship's operational requirements resulted in a final recommendation of two stabilization systems. These studies are continuing in the current year, as well. Preliminary results demonstrate the vast impact on ship operability that an appropriate roll stabilization system has.

Ship Systems

Charles N. Calvano, Associate Professor: Professor Calvano continued his surface ship survivability research, through a joint project with the Institute for Defense Analyses, to explore methods to implement Operationally Oriented Vulnerability Requirements. It is recognized that it would be desirable to design Navy ships to retain a known level of combat capability after sustaining a weapon hit. A methodology for defining the required remaining capability, and the methods for credibly demonstrating compliance with the requirement during the design stage, remain difficult challenges. During 1996 a foundation for definition of the problem, identification of obstacles and outline of approaches to obstacle removal, was made. Continuing work on this project in 1997 is anticipated, with the hoped-for result being agreement between DoD's Operational Test and Evaluation community and the Navy's ship design community concerning workable methods to ensure future Navy ships are designed to "fight hurt" after sustaining damage.

Exploration of the potential utility for Navy applications of non-traditional hull forms was performed, primarily via student theses. A trimaran combatant hull form, which has been explored at University College London, was investigated further to evaluate its potential for ship vulnerability reduction. A related thesis investigating aspects of ship resistance was also completed. This avenue of research is expected to continue in 1997 with examination of the damaged stability characteristics of a modern "tumblehome" hull.

The U.S. Air Force Electronic Systems Command funded work by Professor Calvano (in conjunction with Professor Papoulias) to investigate various ship design options for an Air Force project to put a surveillance radar to sea on a converted ship. The Air Force ship was to be procured from the Navy's Military Sealift Command (MSC), with MSC doing the basic conversion design work. Professor Calvano was asked to review the Air Force requirements and comment on the most desirable way to comply with them and was also asked to review the MSC design, investigating some specific characteristics (seakeeping, roll reduction system, etc.) of the proposed conversion.

Materials Science

Terry R. McNelley, Professor: Professor McNelley has initiated an Army Research Laboratory sponsored program of research into processing, microstructural refinement and fracture toughness enhancement of particle-reinforced metal matrix composite materials. Initial work in this area had been conducted with support from Duralcan-USA, a composites manufacturer located in Detroit, MI, under a CRADA agreement. The Duralcan program demonstrated the feasibility of enhancing composite ductility via controlled thermomechanical processing, leading to the Army program. These materials have demonstrated significant potential for applications such as light armor but further improvement in fracture toughness, both under static and dynamic conditions, is required. Recent efforts have shown that strength/toughness combinations exceeding those of the unreinforced matrix are attainable, thus dispelling the notion that these are inherently brittle materials. Research on processing and superplasticity of aluminum has also continued. Recent efforts have been directed at application of recently developed computer-aided electron microscopy diffraction analysis methods to the characterization of grain boundaries and their development during processing and superplastic deformation. It has been shown that superplastic aluminum alloys transform to a superplastically enabled state by one of two mechanisms. Those which transform via a Gibbs I type of process typically exhibit disordered high-angle boundaries of high interfacial energy. Such materials typically develop coarser grain sizes and require higher superplastic deformation temperatures. Alloys which transform by Gibbs II processes exhibit a high fraction of moderately misoriented boundaries of lower interfacial energy characteristics; microstructures are finer and superplastic response is achieved at lower temperatures and higher strain rates.

Alan G. Fox, Professor: During 1996 the members of Professor Fox's research team in the Center of Materials Science and Engineering were Professor E.S.K. Menon, Dr. Atul Kumar and Dr. Martin Saunders with graduate students Mr. R.Y. Hashimoto, Lt M.E. Gwin and Lt M.K. Greene. On May 31 1996 Dr. Kumar completed his tenure as National Resource Council (NRC) postdoctoral fellow at NPS and left to work as a scientist at the IBM Alameden Research Center. On July 22, 1996, Dr. Saunders from the University of Bristol, U.K., started work at NPS as an NRC postdoctoral fellow and he is working on the quantitative analysis of zone axis convergent beam electron diffraction patterns obtained from intermetallic materials.

In 1996 these group members have been pursuing various projects. Work has been continuing in collaboration with the Carderock Division of the Naval Surface Warfare Center and the Naval Research Laboratory on studies of the mechanical properties of Navy high strength steels and their weldments so that new weld consumables and parent steels for Naval applications can be developed. As in 1995, two projects were undertaken in collaboration with the Naval Air Warfare Center, Pax River, MD. The first involved the characterization of the hot salt corrosion of silicon carbide fiber-reinforced glass ceramic matrix composites which are potential lightweight replacements for nickel-based superalloys in high temperature aero-engine applications and the second concerned the microstructural characterization of new high temperature intermetallic alloys (including TiAl and NiAl) using new methods in x-ray and electron diffraction. This latter project was also supported by the Materials Development Branch of the Wright Patterson Air Force Base, Dayton, OH.

Indranath Dutta, Associate Professor: Professor Dutta's current research efforts are concentrated in the areas of Metal-Matrix Composites and Electronics Packaging Materials Science. In the area of Composites, there are two programs. One is on creep and thermal cycling behavior of fiber reinforced metal-matrix composites at elevated temperatures, which is currently supported by the National Science Foundation. During 1996, the emphasis was on identifying constitutive laws for interfacial deformation. To this end, experimental and modeling of interfacial deformation during fiber pushout testing was conducted. The second program is on the improvement of fracture toughness of discontinuously reinforced aluminum (DRA) composites to via innovative processing routes, and is currently supported by the Army Research Office and the Wright Patterson Air Force Base. Significant progress was made during 1996, and it was shown that both fracture and strength properties of DRA can be improved relative to unreinforced aluminum if the process and microstructural conditions are precise understood and controlled. In the area of Electronics Packaging, Professor Dutta is presently investigating new methods to improve adhesion between metallizations and CVD diamond substrates for hybrid micro-electronics packaging applications, with support from the Naval Surface Warfare Center-Crane Division. During 1996, a new surface modification for diamond was invented and a patent was filed. Current studies are directed at studying the impact of this surface modification on the adhesion between metal and diamond.

OPERATIONALLY-ORIENTED VULNERABILITY REQUIREMENTS FOR SHIPS

Charles N. Calvano, Associate Professor
Department of Mechanical Engineering
Sponsor: Office of the Secretary of Defense

OBJECTIVE: To examine the feasibility of developing a methodology for the use of operationally-oriented vulnerability requirements (OOVRs) for ships which would: (1) keep decision makers informed, beginning early in the acquisition process, as to what weapon hits the ship must be capable of withstanding without sinking or losing the ability to continue to fight effectively, and (2) establish requirements for ship designers in providing the passive protection necessary to achieve this capability.

SUMMARY: The Office of the Secretary of Defense has proposed the institution of operationally-oriented vulnerability requirements for ships. Operationally-oriented vulnerability requirements (OOVRs) would specify minimum levels of combat capability that must remain after a ship is hit by selected threat weapons likely to be encountered in combat. OOVRs would be expected to: (1) keep decision makers informed, beginning early in the acquisition process, as to what threats a ship must be capable of withstanding without sinking and while retaining the capability to fight effectively, and (2) establish requirements for ship designers in reducing vulnerability as necessary to achieve this capability. This project will examine the feasibility of this type of requirement, give examples of the kinds of wording, formats and measures that might be appropriate for such requirements and examine how the imposition of such requirements would affect the ship design and vulnerability assessment process. This task will be performed jointly with the Institute for Defense Analyses (IDA), which will take the lead.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles - Ships and Watercraft

KEYWORDS: Surface ship survivability, submarine survivability, vulnerability

TOTAL SHIP SYSTEMS ANALYSIS AND ASSESSMENT METHODS

Charles N. Calvano, Associate Professor
Department of Mechanical Engineering
Sponsor: Naval Sea Systems Command

OBJECTIVE: To improve methods for enhancing warship military effectiveness and for assessing that effectiveness, through the fostering of education and research.

SUMMARY: The principal objective of this program, which is the subject of a memorandum of agreement between NAVSEA and NPS, is to foster education and research activities on an ongoing, cooperative basis, improving methods for enhancing warship military effectiveness and for assessing that effectiveness. An emphasis on applying total ship system engineering (TSSE) methods to system development process is intended. Desired results are: improvement in the understanding of the relationship between warship vulnerability reduction and warship effectiveness; improvement of the degree to which navy engineers understand and apply total ship systems engineering methods in their work; improvements in techniques for the integration of combat systems and supporting hull, mechanical and electrical ship systems; research which provides tools and methods to enhance the application of TSSE methods; enhanced understanding of the potential and value of simulation and modeling methods in the warship development process; and the development of innovative total ship survivability and assessment tools and methods.

CONFERENCE PRESENTATIONS:

Calvano, C.N., "Comments on Total Ship Systems Engineering in a Combat Systems Environment," American Society of Naval Engineers Combat Systems Symposium, December 1996.

Calvano, C.N., "Systems Engineering in a Ship Design Environment," One-day workshop seminar for American Society of Naval Engineers, Washington, DC, April 1996.

THESES DIRECTED:

Anderson, Eric, "Ship System Study of a Free Electron Laser in a Combatant Ship," Master's Thesis, Naval Postgraduate School, September 1996.

Comar, John, "Conceptual Design of a Fuel Cell Propulsion Plant for a Surface Combatant," Master's Thesis, Naval Postgraduate School, June 1996.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles - Ships and Watercraft

KEYWORDS: Measures of effectiveness, ship performance

SEA BASED DEPLOYMENT SHIP DESIGN ASSESSMENT

Charles N. Calvano, Associate Professor
Department of Mechanical Engineering
Sponsor: U.S. Air Force Electronics Systems Center

OBJECTIVE: Ensure the viability, effectiveness, efficiency and accuracy of ship design plans for ships to be modified to carry the USAF sea-based dual-band transportable radar system; explore alternative commercial ship solutions.

SUMMARY: This program, funded in two fiscal years, is for the evaluation of designs for the modification or procurement of a ship to be used by the USAF electronic systems center (ESC) in the sea based evaluation of a dual band transportable radar system. The ESC and Lincoln laboratories are developing the radar; they will obtain ship engineering and specification preparation services from the Military Sealift Command (MSC), but wish to have an independent review of the design objectives and features by a knowledgeable ship designer. The PI will independently assess the design features developed by MSC and advise ESC as to their desirability or expected effectiveness. The PI will apply his background and expertise in ship design and in total ship systems engineering (TSSE) methods to the evaluation of this process. The PI will also pursue opportunities to use cases and/or issues from this project in his teaching and will encourage the involvement of his officer students in the exploration of appropriate engineering issues as part of their education.

OTHERS: Letter report to the Electronics Systems Center containing results of investigation of roll-reduction systems and the feasibility of the use of alternative propellers on the converted TAGOS ship, to increase transit speed.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles - Ships and Watercraft

KEYWORDS: Surface ship, sea-borne radar

FORCE OVERRIDE RATE CONTROLLER FOR REMOTE ACTUATION

Morris Driels, Professor
Department of Mechanical Engineering
Sponsor: National Aeronautics and Space Administration-Johnson Space Center

OBJECTIVE: The purpose of the project is to study new and cost effective means to implement bilateral force reflection in space based teleoperator systems.

SUMMARY: This project has been inactive this year, due to the unavailability of a suitable thesis student.

DoD KEY TECHNOLOGY AREAS: Space Vehicles, Human Systems Interface, Sensors

KEYWORDS: Teleoperation, force feedback

TARGET ACQUISITION MODEL EVALUATION

Morris Driels, Professor
Department of Mechanical Engineering
Sponsor: U.S. Army TRADOC Analysis Command and Naval Postgraduate School

OBJECTIVE: The DoD has at its disposal many computer models which enable analysts to simulate various phases of target acquisition and combat scenarios. The project involved examination of selected models, and cataloging these models in a Target Acquisition Handbook. This Handbook is in support of the Target Acquisition Models Library under development by the respective DoD's of ABCA (Australia, Britain, Canada and America).

SUMMARY: The research focused on the following models: The Acquire Search Model, the IDA Search Model, the ORACLE Visual Performance Model, The NVESD Television Model, Acquire Version 1.0, FLIR92, and the NVESD Imaging Infrared Model. Appropriate software was obtained from the responsible agency, and each model was exercised over a wide range of input parameters to perform a basic sensitivity study, and determine appropriate bounds for the input parameters. Each model was evaluated according to pre-specified criteria, and include a program description, computer requirements, associated models, applicable operational situations and included factors, model inputs and outputs, and model assessment.

PUBLICATION:

Driels, M., Handbook of Target Acquisition Models, Release 1.0, Tradoc Analysis Command, White Sands, October 1996.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Command, Control and Communications, Modeling and Simulation

KEYWORDS: Target acquisition, combat modeling and simulation

A/S AND S/S TARGET ACQUISITION METHODOLOGIES

Morris Driels, Professor
Department of Mechanical Engineering
Sponsor: U.S. Army Materiel Systems Analysis Activity

OBJECTIVE: The project will integrate three separate computer models to produce a target acquisition planning program. This program will enable pilots on ground attack missions to predict the best time of day and the best approach heading to the target, and will provide a visualization of the target area at the point of weapon release.

SUMMARY: This project is conducted jointly by NPS, Naval Air Warfare Center-Weapons Division (NAWC), and the U.S. Army AMSAA. The work involved the integration of three target acquisition and planning modules: EOTDA, which is a weather/atmospherics program predicting target signatures as a function of location and time of day, TAPPS, which is a target masking prediction tool providing contours of clear line of sight around a target partially obscured by cultural features, and PVG, which is a high resolution terrain and feature rendering program for providing realistic imagery of the target area.

Each part of the work was performed by the appropriate research group, with NPS handling the Perspective View Generator (PVG) part. Work to date has integrated the first two components in a PC-Windows environment, and the final integration and validation of the complete model will be conducted in FY97.

CONFERENCE PRESENTATIONS:

Driels, M., "Integrated Target Acquisition Planning Model" Air-to-Surface Working Group Meeting, Eglin AFB, FL, April 1996.

Driels, M., "Integrated Target Acquisition Planning Model" Air-to-Surface Working Group Meeting, Eglin AFB, FL, October 1996.

Driels, M., "Target Acquisition Overview," JMEM A/S Operational Users Working Group Meeting, NAS Miramar, CA, March 1966.

THESES DIRECTED:

Darlak J., "Calculation of Target Masking Effects for Air to Surface Ordnance Delivery," Master's Thesis, Naval Postgraduate School, December 1996.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Command, Control and Communications, Modeling and Simulation.

KEYWORDS: Target acquisition, combat modeling and simulation.

CREEP OF FIBER REINFORCED METAL MATRIX COMPOSITES

I. Dutta, Associate Professor
Department of Mechanical Engineering
Sponsor: National Science Foundation

OBJECTIVE: To investigate the mechanisms of creep in metal-matrix composites

SUMMARY: The goal of this project is to develop a phenomenological understanding of the mechanisms operative during high temperature deformation of metal matrix composites reinforced by continuous fibers. A combination of experimental and analytical means are being utilized to develop a model for creep/thermal cycling, with the eventual objective of generating transient deformation mechanism maps.

PUBLICATIONS:

Dutta, I., and Derby, B., "An Analytical Treatment for the Determination of Time-Dependent High Temperature Interface Properties in Metal-Matrix Composites via Fiber-Pushout Tests," 1996 TMS Fall Meeting, October 1996.

Dutta, I., and Funn, J.E., "Creep Behavior of Near-Interface Regions in Continuous Fiber Reinforced Metal-Matrix Composites," submitted to Scripta Metallurgica et Materialia.

DoD KEY TECHNOLOGY AREAS: Materials, Processes and Structures

KEYWORDS: Metal matrix composites, creep/thermal cycling

PROCESSING AND FRACTURE OF PARTICULATE REINFORCED METAL-MATRIX COMPOSITES

I. Dutta, Associate Professor
Department of Mechanical Engineering
Sponsors: U.S. Army Research Office and U.S. Air Force Material Command

OBJECTIVE: To correlate processing, microstructure and fracture properties in particulate reinforced aluminum (PRA) composites.

SUMMARY: The purpose of this project is to investigate microstructural development during processing of PRA, specifically with respect to the evolution of particulate distribution and matrix grain and precipitate structure, and to evaluate the impact of fracture properties and mechanisms. The eventual goal is to design the material microstructure in such a way so as to result in substantially improved fracture toughness, while retaining the stiffness and strength advantage of PRA relative to unreinforced aluminum alloys.

PUBLICATIONS:

Dutta, I., and Majumdar, B.S., "Effect of Processing on the Fracture Characteristics of a 6092 Al Composite Reinforced with SiCp," Materials Science Forum, Vols. 217-222 (1996) Proceedings 5th International Conference on Aluminum Alloys, Grenoble, France, p. 1473.

McNelley, T.R., Ballou, M.A., and Dutta, I., "A Microstructural Investigation of Particle Redistribution During Thermo-Mechanical Processing of a Cast 6061 Al - Al_2O_3 MMC," to appear in 'Cast Metal Matrix Composites', P.K. Rohatgi et al., eds., Proceedings 1996 TMS Fall Meeting.

CONFERENCE PRESENTATIONS:

Dutta, I., Majumdar, B.S., Seetharaman, V., and McNelley, T.R., "Dependence of Mechanical Properties of a SiCp-6092 Al Composite on Post-Fabrication Deformation Processing," presented at 125th TMS Annual Meeting, Anaheim, CA, February 1996.

Dutta, I., Quiles, F.N., Majumdar, B.S., and McNelley, T.R., "Effect of Secondary Processing on the Strength-Fracture Toughness Relationships in SiCp-Aluminum Composites," presented at the 1996 TMS Fall Meeting, October 1996.

THESIS DIRECTED:

Quiles, F.N., "An Investigation of the Effects of Secondary Processing on the Fracture Properties of a 6xxx-SiCp MMC," Master's Thesis, Naval Postgraduate School, June 1996.

DoD KEY TECHNOLOGY AREAS: Materials, Processes and Structures

KEYWORDS: Particulate reinforced aluminum composites, fracture toughness

METALLIZATION OF CVD DIAMOND FOR ELECTRONIC PACKAGING

I. Dutta, Associate Professor
Department of Mechanical Engineering
Sponsor: Naval Surface Warfare Center-Crane Division

OBJECTIVE: To develop approaches for metallization of CVD Diamond.

SUMMARY: The purpose of this project is to develop innovative approaches for producing adherent metallizations on CVD Diamond, which is an excellent thermal management material that is being currently considered for high-end

electronic packages. Since metals do not naturally adhere to diamond, there is a need to develop new surface modifications for diamond to make metals stick to diamond

PUBLICATIONS:

Menon, E.S.K., and Dutta, I., "Processing and Characterization of Aumina Thin Films on CVD Diamond Substrates for Producing Adherent Metallizations," Journal of Materials Research, in review.

Menon, E.S.K., and Dutta, I., "A Surface Treatment of CVD Diamond Substrates for Producing Adherent Metallizations," Appl. Physic. Letter., 68 p. 2951, 1996.

CONFERENCE PRESENTATION:

Menon, E.S.K., Kumar, A., Dutta, I., and Fox, A.G., "Elemental Distributions Near Interfaces - Experimental Studies," invited paper presented at 1996 TMS Fall Meeting, to appear in Metallurgical Transactions A.

OTHER:

Dutta, I., and Menon, E.S.K., "Surface Modification of CVD Diamond Substrates for Producing Adherent Thick and Thin Film Metallizations for Electronics Packaging," U.S. Patent Application # NC 77524, filed January 1996.

DoD KEY TECHNOLOGY AREAS: Materials, Processes and Structures

KEYWORDS: Metallizations, CVD diamond, thermal management

DIFFRACTION METHODS FOR THE ACCURATE MEASUREMENT OF STRUCTURE FACTORS AND CHARGE DENSITIES OF ELEMENTS AND INTERMETALLIC ALLOYS

A.G. Fox, Professor
E.S.K. Menon, Research Assistant Professor
M. Saunders, National Research Council Postdoctoral Associate
Center for Materials Science and Engineering
Department of Mechanical Engineering
Sponsors: U.S. Air Force Material Command, Naval Surface Warfare Center-Carderock Division, and Naval Postgraduate School

OBJECTIVE: To accurately measure the low-angle structure factors of elements and alloys by various diffraction methods so that their electronic bonding mechanisms can be investigated.

SUMMARY: A knowledge of the distribution of bonding electrons in crystalline solids can give important information about their physical properties. One way to gain such knowledge is to accurately measure the low-angle structure factors of the materials of interest by some means, and then use these to generate maps of the electron charge distributions. In the past we have used both electron and x-ray diffraction to measure the low-angle structure factors of several elements and intermetallic alloys with high accuracy. The lattice parameters and Debye-Waller factors were measured by x-ray diffraction and the structure factors by the critical voltage technique in electron diffraction. More recently we have been making these measurements using the energy filtering transmission electron microscope which has been recently installed at NPS. This has allowed us to fully quantify energy filtered convergent beam electron diffraction patterns and determine the low-angle structure factors of elements and alloys with an accuracy far greater than previously achieved. This is leading to a vastly improved understanding of the nature of bonding in crystalline solids.

PUBLICATIONS:

Fox, A.G., and Menon, E.S.K., "Measurement of the Debye-Waller Factors of Elements and Binary Compounds by Convergent Beam Electron Diffraction," in Proceedings of Eurem '96, Dublin, Eire, August 1996.

Saunders, M., Midgley, P.A., Walsh, T.D., Menon, E.S.K., Fox, A.G., and Vincent, R., "Quantitative Energy-Filtered CBED - Matching Theory to Experiment," in Proceedings of the 15th Pfefferkorn Conference, Silver Bay, NY, May 1996.

DoD KEY TECHNOLOGY AREAS: Materials, Processes and Structures

KEYWORDS: Convergent beam electron diffraction, structure factor measurement, bonding charge density

MICROSTRUCTURAL STUDIES OF SILICON FIBER REINFORCED GLASS-CERAMIC COMPOSITES FOR GAS TURBINE APPLICATIONS

A.G. Fox, Professor
E.S.K. Menon, Research Assistant Professor
A. Kumar, National Research Council Postdoctoral Associate,
Center for Materials and Engineering
Department of Mechanical Engineering
Sponsors: U.S. Air Force Material Command, Naval Surface Warfare Center-Carderock Division, and Naval Postgraduate School

OBJECTIVE: To investigate the hot corrosion of silicon fiber reinforced glass-ceramic matrix composites.

SUMMARY: The U.S. Navy and Air Force have ongoing programs of research into silicon fiber reinforced glass-ceramic matrix composites (CMCs) which have many potential uses for gas turbine components. The high strength, toughness and resistance to high temperatures and low density of CMCs could allow a considerable increase in gas turbine engine efficiency if they could be used to replace heavy metallic parts. Unfortunately, aircraft operating environments are often very severe and any CMC components developed must be resistant to high temperature environments containing salt and aviation fuel which may be rich in sulfur. This work is using electron microscopy and x-ray diffraction to elucidate the mechanisms of hot salt corrosion in lithium, calcium and magnesium alumino silicates reinforced with silicon carbide fibers. The results of this work are helping to determine which CMCs are suitable for DoD applications.

PUBLICATIONS:

Kumar, A., Fox, A.G., and Wang, S.W., "Mechanisms of Hot Corrosion of a SiC Fiber-Reinforced Glass Ceramic," in Proceedings of the American Ceramic Society Conference, Cocoa Beach, FL, January 1996.

Fox, A.G., Kumar, A., and Menon, E.S.K., "Electron Spectroscopic Imaging of Interfaces in a Nicalon (Si-C-O) Fiber-Reinforced Glass-Ceramic Matrix Composite," in Proceedings of the Recent Advancement of Interfacial Materials Science on Composite Materials '96 Conference, Kyushu University, Japan, May 1996.

Knowles, K.M., Kumar, A., and Fox, A.G., "Microstructural Characterization of As-Processed and Oxidized Si-C-O Fibre-Reinforced Barium Magnesium Aluminosilicates," in Proceedings of Microscopy of Oxidation III Conference, Cambridge, U.K., September 1996.

CONFERENCE PRESENTATIONS:

Menon, E.S.K., Kumar, A., Dutta, I., and Fox, A.G, "Elemental Distributions Near Interfaces - Experimental Studies" presented at TMS Fall Meeting, Cincinnati, OH, October 1996.

DoD KEY TECHNOLOGY AREAS: Materials, Processes and Structures

KEYWORDS: Fiber-reinforced glass-ceramic matrix composites, hot corrosion

MICROSTRUCTURES AND MECHANICAL PROPERTIES OF HIGH-STRENGTH, LOW-ALLOY (HSLA) STEELS AND THEIR WELDMENTS

A.G. Fox, Professor
E.S.K. Menon, Research Assistant Professor
Center for Materials and Engineering
Department of Mechanical Engineering
Sponsors: Naval Surface Warfare Center-Carderock Division, Office of Naval Research, and Naval Postgraduate School

OBJECTIVE: To investigate the microstructure and mechanical properties of ULC, HY and HSLA 80-130 series steels and their weldments to evaluate new weld consumables and parent steels for Naval shipbuilding applications.

SUMMARY: In recent years the U.S. Navy has been replacing the HY80-100 series of high strength alloy steels with their high-strength, low-alloy (HSLA) equivalents. This is being done because the stringent weld pre-heat requirements associated with the HY steels are not necessary for the HSLA series. So, despite the higher manufacturing costs of high-strength, low-alloy steels, the U.S. Navy should make significant savings by changing over to HSLA or ultra low carbon (ULC) steels for ship and submarine construction. In order to extract the maximum benefit from these newly developed steels it is also necessary to develop improved weld filler wires. This project supports these objectives with fundamental physical metallurgy studies at NPS using advanced optical and electron microscopy techniques.

PUBLICATIONS:

Fox, A.G., Eakes, W., and Franke, G.L., "The Effect of Small Changes in Flux Basicity on the Acicular Ferrite Content and Mechanical Properties of Submerged-Arc Weld Metal of Navy HY-100 Steel," Welding Journal Research Supplement, Vol. 75, 330s - 342s, 1996.

Fox, A.G., Eakes, M.W., and Wong, R.J., "The Effect of Cover Gas Composition on the Microstructure and Mechanical Properties of Gas-Metal-Arc Weld Metal of Navy HSLA-100 Steel," in Proceedings of the Joining of Advanced Materials, an International Conference on Advances in Welding Technology sponsored by EWI, Columbus, OH, November 1996.

CONFERENCE PRESENTATION:

Menon, E.S.K., Kumar, A., Dutta, I., and Fox, A.G, "Elemental Distributions Near Interfaces - Experimental Studies," TMS Fall Meeting, Cincinnati, OH, October 1996.

THESIS DIRECTED:

Gwin, M.E., "Factors Affecting the Impact Toughness of Ultra-Low Carbon Steel Weld Metal," Master's Thesis, Naval Postgraduate School, September 1996.

DoD KEY TECHNOLOGY AREAS: Materials, Processes and Structures

KEYWORDS: Ultra low carbon steel, welding

QUANTITATIVE AND QUALITATIVE PEELS SPECTROSCOPY USING THE GATAN IMAGING FILTER

A.G. Fox, Professor
E.S.K. Menon, Research Assistant Professor
M. Saunders, National Research Council Postdoctoral Research Associate
Center for Materials and Engineering
Department of Mechanical Engineering
Sponsors: Unfunded

OBJECTIVE: To investigate the capability of a GATAN imaging filter to perform both quantitative and qualitative parallel electron energy loss spectroscopy (PEELS).

SUMMARY: Parallel electron energy loss spectroscopy (PEELS) is commonly used to obtain microchemical information in the transmission electron microscope (TEM). Indeed most of the TEM research carried out in the Center for Materials Science involves the use of PEELS or PEELS imaging to some extent. However the use of a slow scan CCD as the detection device for PEELS spectra in the GATAN imaging filter may have important implications for the use of this technique for both quantitative and qualitative microanalysis. In particular we have discovered that 'blooming' of the CCD camera can lead to erroneous results. This is a new project which was started in CY 96.

DoD KEY TECHNOLOGY AREAS: Materials, Processes and Structures

KEYWORDS: Transmission electron microscopy, PEELS, imaging filter

CONVECTIVE HEAT TRANSFER INDUCED BY STRONG ACOUSTIC FIELDS

Ashok Gopinath, Assistant Professor
Department of Mechanical Engineering
Sponsor: Naval Postgraduate School

OBJECTIVE: To develop correlations for calculating convective heat transfer rates induced by strong acoustic fields with application to heat exchanger design for thermoacoustic engines.

SUMMARY: This work was motivated by the need to provide a better understanding of the heat transfer behavior in internal oscillatory flows with application to the improvement of the design of heat exchangers in thermoacoustic engines. As per the work proposed, an experimental rig was constructed to first explore geometries of fundamental interest, such as a cylinder, which make up one of the basic component shapes in a heat exchanger. Two students from the Space Systems curriculum were involved in this project in CY95 and their experimental and theoretical contributions were summarized earlier.

In the second phase of the project conducted during FY96 the experimental goals were pursued further and a student working on his thesis contributed towards covering a wider parameter regime than had been achieved before. A fundamentally different experimental technique was employed based on the RTD method of temperature measurement using fine platinum wires of various diameters to cover various parameter regimes. The large amount of experimental data that was gathered gives considerable insight into the unexpected behavior of the heat transfer coefficient over different parameter values, and indicates that some caution is required in applying conventional wisdom to convective heat transfer behavior in oscillatory flows. This data was presented at a conference in December 1996 where it was well received, and based on the strength of which the PI has been invited to make a keynote presentation on this subject at an upcoming conference.

A simultaneous theoretical study of the role of acoustic streaming was also carried out and it was found that steady flows generated in the stack region of a thermoacoustic engine are of significant magnitude, confirming results of LDV experiments performed earlier. These results too were presented at a conference in May 1996.

CONFERENCE PRESENTATIONS:

Gopinath, A., "Acoustic Streaming in a Resonant Channel," 131st Meeting of the Acoustical Society of America, IN, Indiana, May 1996 (abstract in Journal of the Acoustical Society of America, Vol. 99, No. 4, Pt. 2, p. 2540, April 1996).

Gopinath, A., Harder, D.R., and Bridenstine, M., "Convective Heat Transfer from a Cylinder in a Resonant Acoustic Field," 3rd Joint Meeting of the Acoustical Society of America and the Acoustical Society of Japan, Honolulu, HI, December 1996 (abstract in Journal of the Acoustical Society of America, Vol. 100, No. 4, Pt. 2, p. 2847, October 1996).

THESIS DIRECTED:

Bridenstine, M., "Convective Heat Transfer from a Vertical Cylinder in a High Amplitude Resonant Sound Field," Master's Thesis, Naval Postgraduate School, September 1996.

DoD KEY TECHNOLOGY AREAS: Environmental Quality, Other (Energy systems)

KEYWORDS: Thermoacoustics, acoustic streaming, heat transfer correlations, modeling and simulation, recovery factors, oscillatory flows

HEATING SYSTEM ANALYSIS ABOARD COAST GUARD CUTTERS

Ashok Gopinath, Assistant Professor
Department of Mechanical Engineering
Sponsor: Unfunded

OBJECTIVE: To explore the cost-saving option of replacing steam with hot water for heating aboard Coast Guard cutters without a major overhaul in the existing heat exchange equipment.

SUMMARY: The typical compartment heating system on a Coast Guard cutter was studied with the objective of replacing circulating steam with hot water as the medium for providing the heating. Such a study was motivated by the need to phase out bulky, expensive and trouble-prone steam generating equipment on the cutters, with more reliable hot water systems without sacrificing the heating capabilities. A conservative analysis of the typical heat exchangers in use aboard these cutters showed that the steam did provide marginally higher heat transfer rates, not due to any inherent property of the steam or latent change effects, but primarily due to the capability of being at a higher temperature. Judging from the heat transfer analysis it was concluded that the possibility of using currently installed heat exchangers in a water-based hydronic system with minimal modifications is a viable option.

THESIS DIRECTED:

Hurley, J.T., "Analysis of Steam and Hydronic Compartment Heating Systems Aboard U.S. Coast Guard Cutters," Master's Thesis, Naval Postgraduate School, June 1996.

DoD KEY TECHNOLOGY AREAS: Other (Energy systems)

KEYWORDS: Heat transfer, heat exchangers, compartment heating

EXPERIMENTAL STUDY OF A PLATE AND FRAME HEAT EXCHANGER

Ashok Gopinath, Assistant Professor
Department of Mechanical Engineering
Sponsor: Unfunded

OBJECTIVE: To conduct an experimental investigation of the performance characteristics of a plate and frame heat exchanger and thereby also establish a rig for demonstration/instruction purposes.

SUMMARY: Plate and frame heat exchangers are commonly used by the Navy aboard ships, and on bases for routine heat exchange applications. This study was designed to investigate the performance characteristics of such a heat exchanger provided by Tranter, Inc. It was carefully instrumented to measure flow rates and temperatures, and set up in the lab in a flow circuit to study heat exchange between a model water-water system. The measured performance showed very good agreement with available correlations in the literature, and also with the manufacturer's data, and will serve as a good model system to support heat exchanger demonstration/instruction.

THESIS DIRECTED:

Plath, D.R., "Experimental Performance Studies of a Plate-Frame Heat Exchanger," Master's Thesis, Naval Postgraduate School, December 1996.

DoD KEY TECHNOLOGY AREAS: Other (Energy Systems)

KEYWORDS: Heat transfer, plate and frame heat exchangers

THERMOACOUSTIC EFFECTS AT A SOLID-FLUID BOUNDARY: THE ROLE OF A SECOND ORDER THERMAL EXPANSION COEFFICIENT

Ashok Gopinath, Assistant Professor
Department of Mechanical Engineering
Sponsor: National Aeronautics and Space Administration

OBJECTIVE: To conduct fundamental material and transport studies on thermoacoustic phenomena in microgravity with possible future experiments aboard Space Shuttle flights.

SUMMARY: This project is a 3-year (FY97 through FY99) new start and work has only just begun. The studies deal with thermoacoustics and the study of a little known second order thermal expansion coefficient by exploiting the near absence of buoyancy forces in microgravity.

CONFERENCE PRESENTATION:

Gopinath, A., "Thermoacoustic Effects at a Solid-Fluid Boundary: The Role of a Second Order Thermal Expansion Coefficient," Third Microgravity Fluid Physics Conference, Cleveland, OH, June 1996, NASA Conference Publication 3338, pp. 661-666, 1996.

DoD KEY TECHNOLOGY AREAS: Materials, Processes and Structures, Modeling and Simulation

KEYWORDS: Thermoacoustics, acoustic streaming, acoustic levitation, thermophysical property measurement, thermodynamic moduli, oscillatory flows, asymptotic techniques

ACOUSTIC STREAMING IN MICROGRAVITY: FLOW STABILITY AND HEAT TRANSFER ENHANCEMENT

Ashok Gopinath, Assistant Professor
Department of Mechanical Engineering
Sponsor: National Aeronautics and Space Administration

OBJECTIVE: To conduct fundamental material and transport studies of acoustic streaming related phenomena in microgravity with possible future experiments aboard Space Shuttle flights.

SUMMARY: This project is a 3-year (FY97 through FY99) new start and work has only just begun. The studies deal with fluid/heat transport due to acoustic streaming in microgravity.

CONFERENCE PRESENTATION:

Trinh, E.H., and Gopinath, A., "Acoustic Streaming and Heat and Mass Transfer Enhancement," Third Microgravity Fluid Physics Conference, Cleveland, OH, June 1996, NASA Conference Publication 3338, pp. 791-796, 1996.

DoD KEY TECHNOLOGY AREAS: Other (Energy Systems)

KEYWORDS: Acoustic streaming, heat transport, asymptotic techniques

TIME DOMAIN METHODS IN STRUCTURAL SYNTHESIS

Joshua H. Gordis, Assistant Professor
Department of Mechanical Engineering
Sponsor: Naval Postgraduate School

OBJECTIVE: This project is concerned with the theoretical development and computational implementation of a time domain theory for structural synthesis.

SUMMARY: This research concerns the development of a time domain theory for structural synthesis. This new theory provides the previously unavailable capability of performing exact transient structural synthesis, regardless of damping with the order of the synthesis being independent of model size. The method is based on Volterra integral equations derived from the convolution integral which describe substructure coupling and structural modification. The numerical solution of the integral equations yields a triangular linear system which is solved for the synthesized system transient responses/coupling forces, with no factorization or eigen solution required. The approach is currently being extended to treat local nonlinearities, such as in a nonlinearly shock isolated system.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Structural dynamics, time domain, synthesis, identification

STRUCTURAL DYNAMICS OF THE RAH-66 COMANCHE HELICOPTER

Joshua H. Gordis, Assistant Professor
Department of Mechanical Engineering
Sponsor: U.S. Army Aviation and Technology Command

OBJECTIVE: Technical support is provided to the U.S. Army Aviation and Technology Command, St. Louis, for the structural dynamics and vibration of the RAH-66 Comanche.

SUMMARY: The RAH-66 Comanche helicopter is the U.S. Army's attack helicopter for the 21st Century. During 1996, the Comanche began a program of ground vibration and flight tests, intended to validate structural dynamic

performance of the airframe and to demonstrate the helicopter's performance characteristics. These tests typically uncover dynamics problems with rotor-fuselage coupling and forced response. In order to ensure the survival of the Comanche program, these problems, when discovered, must be quickly resolved. This effort provides rapid technical support to the Comanche Program, to resolve structural dynamics problems. A proposal for continued FY96 funding has been submitted.

DoD KEY TECHNOLOGY AREAS: Air Vehicles.

KEYWORDS: Helicopter, Comanche, structural dynamics

SHOCK ISOLATION ANALYSIS OF PALADIN FIRE CONTROL COMPUTER

Joshua H. Gordis, Assistant Professor
Department of Mechanical Engineering
Sponsor: U.S. Army-Picatinny Arsenal

OBJECTIVE: The modeling and analysis of the isolation system for a new fire control computer to be mounted in the U.S. Army Paladin self-propelled Howitzer, a tracked vehicle.

SUMMARY: Picatinny Arsenal was charged with replacing the fire control computer on the Paladin self-propelled Howitzer with a COTS (commercial-off-the-shelf) computer. This non-hardened computer required very effective isolation systems. This project was concerned with the computer modeling of the computer on its isolation system, and the simulation of gun-fire shock to determine adequacy of the isolation design.

PUBLICATION:

Gordis, J.H., "Shock and Vibration Analysis of the Paladin AFCS Computer on Two-Layer Isolation" prepared for Product Manager, Paladin/FAASV, U.S. Army, Bldg. 171, Picatinny Arsenal, NJ 07806-5000.

CONFERENCE PRESENTATION:

Radwick, J.L., Florence, D.E., and Gordis, J.H., "Optimal Design of One and Two-Layer Isolation Systems for Shock and Vibration." Proceedings of the 67th Shock and Vibration Symposium, Vol. 1, Monterey, CA, 18-22 November 1996. pp. 457-468.

DoD KEY TECHNOLOGY AREAS: Ground Vehicles

KEYWORDS: Shock, vibration, isolation, optimum design, tracked vehicles

BUGS: BASIC UXO GATHERING SYSTEM - MODELING AND SIMULATION

A.J. Healey, Professor
Department of Mechanical Engineering,
Sponsor: Naval Engineering Ordnance Technical Center

OBJECTIVE: This work is being undertaken to provide a graphics based simulator and a rapid modeling capability for evaluating the clearance performance of multiple cooperating vehicles in UXO gathering and minefield operations. The work involves the development and the evaluation of various robot system control concepts as proposed for the BUGS system.

SUMMARY: The graphics simulator code runs on a high end SGI workstation currently an ONYX Reality Engine workstation and has been developed using the "inventor" and "performer" tool kit. It is planned to use the simulator as a training tool for the U.S. Army/Marine Corps to evaluate sensor technology as well as control methodologies in semi-

realistic environments in relation to the performance of the overall BUGS system concepts for land-based ordnance clearance operations. The simulator is built around a terrain base taken from the Marine Corps 29 Palms facility and a small subset of that data base has been selected as a test site for evaluation of clearance operations. Vegetation has been included as uniformly distributed randomly dispersed objects added to the data base. Munitions simulated include Mk 118 anti-personnel munitioructures

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Composites, metal matrix composites, processing, finite element modeling

OPTIMIZATION TECHNIQUE USING THE FINITE ELEMENT METHOD AND ORTHOGONAL ARRAYS

Young W. Kwon, Associate Professor
Department of Mechanical Engineering
Sponsor: Unfunded

OBJECTIVE: The goal was to develop a design optimization technique that could be used interactively by design engineers to approach an optimal design with minimal computational effort.

SUMMARY: Finite Element Analysis (FEA) has been popular in engineering designs. The design process, especially for an optimum design, requires lots of design iterations which also demand many FEA. FEA in general is less expensive than physical testing, but FEA of a practical design problem is still time consuming and expensive, especially for many design iterations. As a result, a simple and efficient design optimization technique was developed using the orthogonal array concept. The concept of orthogonality refers to the statistically independent or balanced parameters that make up the columns of the orthogonal array. Therefore, this array could provide useful information regarding overall design sensitivities using a small number of FEA computations. Using those overall design sensitivities, an optimum or near optimum design could be arrived quickly. The developed technique was applied to structural design optimization examples with discrete and/or continuous design variables.

PUBLICATION:

Young, S.H., and Kwon, Y.W., "An Optimization Technique Using the Finite Element Method and Orthogonal Arrays," Recent Advances in Solids/ Structures and Application of Metallic Materials, PVP-Vol. 342/MD-Vol. 72, American Society of Mechanical Engineers, 1996.

CONFERENCE PRESENTATION:

Young, S.H., and Kwon, Y.W., "An Optimization Technique Using the Finite Element Method and Orthogonal Arrays," ASME International Mechanical Engineering Congress and Exposition, Atlanta, GA, 17-22 November 1996.

THESIS DIRECTED:

Young, S.H., "An Optimization Technique Using the Finite Element Method and Orthogonal Arrays," Master's Thesis, Naval Postgraduate School, September 1996.

DoD KEY TECHNOLOGY AREAS: Other (Design)

KEYWORDS: Design optimization, finite element method, orthogonal array, design sensitivity, structural design

GRAIN BOUNDARY CHARACTER AND SUPERPLASTICITY

T.R. McNelley, Professor,
Department of Mechanical Engineering
Sponsor: Unfunded

OBJECTIVE: The goal of this program is to study the role of grain boundaries in fine-grained, superplastic aluminum alloys and the development of such grain boundaries during thermomechanical processing of these materials.

SUMMARY: Recently developed computer-aided electron microscopy diffraction analysis methods have been applied to the investigation of the role of grain boundaries in several superplastic aluminum alloys. These materials have been examined following various thermomechanical processing schedules and deformation histories. Aluminum alloys 5083, 7475 and laboratory-processed 2519 are observed to transform to a refined, superplastic microstructure via primary (discontinuous) recrystallization reaction involving the formation and migration of high-angle grain boundaries. However, Supral 2004, Al-10Mg-0.1Zr and Al-5Ca-5Zn materials transform by a continuous process. These different transformation processes may be distinguished by distinctly different grain boundary misorientation distributions. Primary recrystallization produces a random distribution similar to that predicted by Mackensie for randomly oriented cubes and the resultant superplastic response is often relatively limited. The continuous reaction results in a bi-modal misorientation distribution, with many moderately misoriented boundaries of misorientation near 10 degrees, and a much more highly superplastic response.

PUBLICATIONS:

McNelley, T.R., and McMahon, M.E., "Analyzing Superplastic Microstructures Using Interactive EBSP Methods," Journal of the Minerals, Metals and Materials Society, 48, No. 2, p. 58, February 1996.

McNelley, T.R., and McMahon, M.E., "An Investigation by Interactive EBSP Analysis of Processing and Superplasticity in an Aluminum-Magnesium Alloy," Metallurgical and Materials Transactions A, 27A, pp. 2252, 1996

McNelley, T.R., McMahon, M.E., and Hales, S.J., "An EBSP Investigation of Alternate Microstructures for Superplasticity in Aluminum-Magnesium Alloys," in press, Scripta Materialia

McNelley, T.R., McMahon, M.E., and Hales, S.J., "Grain Boundary Development during Processing of Superplastic Aluminum Alloys," in Proceedings of ReX'96: Third International Conference on Recrystallization and Related Phenomena (T.R. McNelley, ed.), in press, MIAS, 1997.

CONFERENCE PRESENTATIONS:

McNelley, T.R., and McMahon, M.E., "Application of EBSP Analysis Methods to Distinguish Mesotexture in Superplastic Aluminum-Magnesium Alloys," Sixth Annual Conference: Frontiers of Electron Microscopy in Materials Science, Oak Park, IL, 6 June 1996.

McNelley, T.R., McMahon, M.E., and Hales, S.J., "Grain Boundary Development during Processing of Superplastic Aluminum Alloys," ReX'96: Third International Conference on Recrystallization and Related Phenomena, Monterey, CA, 23 October 1996.

THESIS DIRECTED:

McMahon, M.E., "Grain Boundary Development in Superplastic Aluminum Alloys," Doctor of Philosophy in Mechanical Engineering, Naval Postgraduate School, December 1996.

DoD KEY TECHNOLOGY AREAS: Materials, Processes and Structures

KEYWORDS: Aluminum, superplasticity, recrystallization, grain boundaries, thermomechanical processing

A KNOWLEDGE-BASED APPROACH TO FRACTURE TOUGHNESS IMPROVEMENT VIA PROCESSING FOR PARTICULATE-REINFORCED ALUMINUM METAL MATRIX COMPOSITES

T.R. McNelley, Professor
Department of Mechanical Engineering
Funding: U.S. Army Research Office and U.S. Army Research Laboratory

OBJECTIVE: The goal of this program is to obtain improved combinations of strength, ductility and toughness in Al-based metal-matrix composite materials by thermomechanical processing.

SUMMARY: Discontinuously reinforced Al matrix composite materials have many attractive properties but lack adequate ductility and toughness for many applications. Dramatic improvements in composite ductility have been attained in extruded 6061 Al-Al_2O_3 processed using methods designed to redistribute the Al_2O_3 particles as well as achieve a fully recrystallized matrix grain structure via particle-stimulated nucleation of recrystallization. Further improvements in ductility have been obtained with use of controlled heat treatments on processed material. The influence of deformation temperature on redistribution of particles during processing has been investigated by controlled deformation of samples in a channel die. Fracture toughness improvements in extruded powder metallurgy 6092 Al-SiC material have been demonstrated and strength-toughness combinations equivalent to those of the unreinforced matrix alloy have been attained.

PUBLICATIONS:

Dutta, I., and Majumdar, B.S., "Effect of Processing on the Fracture Characteristics of a 6092 Al Composite Reinforced with SiC_p," to appear in Proceedings of ICAA-5, Grenoble, France, 1997

McNelley, T.R., Ballou, M.A., and Dutta, I., "A Microstructural Investigation of Particle Redistribution during Thermomechanical Processing of a Cast 6061 Al - Al_2O_3 MMC," to appear in Proceedings of the Symposium on Cast Metal Matrix Composites: Processing and Applications (P. Rohatgi and P.A. Khan, eds.), Warrendale, PA, 1997

CONFERENCE PRESENTATIONS:

Dutta, I., and McNelley, T.R., "An Investigation of the Effect of Post-Fabrication Processing on Microstructure and Properties of a SiC_p - 6092 Al Composite," 125th Annual Meeting of TMS, Anaheim, CA, 6 February 1996

McNelley, T.R., Ballou, M.A., and Dutta, I., "A Microstructural Investigation of Particle Redistribution during Thermomechanical Processing of a Cast 6061 Al - Al_2O_3 MMC," Fall Meeting of ASM and TMS, Cincinnati, OH, 8 October 1996

THESIS DIRECTED:

Boyle, K.P., "The Role of Particle Cracking in Dilatation during Tensile Straining of a Cast and Thermomechanically Processed 6061 Al - 20 Volume Percent Al_2O_3 Metal Matrix Composite," Master's Thesis, Naval Postgraduate School, September 1996.

DoD KEY TECHNOLOGY AREAS: Materials, Processes and Structures

KEYWORDS: Metal-matrix composites, processing, particle distribution, fracture toughness

CONTINUOUS MEASUREMENT OF AGING USING EDDY CURRENT SENSORS DURING HEAT TREATMENT OF PRECIPITATION HARDENING ALLOYS

T.R. McNelley, Professor
Department of Mechanical Engineering
Sponsor: Naval Air Warfare Center-Aircraft Division

OBJECTIVES: The goal of this program is the development of sensors for the continuous measurement of the aging response during heat treatment of a precipitation hardening alloy. Intelligent processing requires such a sensor to monitor material response in real time and provide input to a controller.

SUMMARY: This research has involved the development of a sensor system for the continuous monitoring of the aging response of 7075 Aluminum alloy during intelligent heat treatment of the material. Intelligent processing requires sensors to monitor material response in real time. A sensor consisting of two spiral-wound probes and a bridge circuit with a bridge carrier amplifier (BCA) has been used to obtain data reflecting the changing resistivity of 7075 Aluminum during either isothermal or multi-step aging treatments. Transient effects during initial rapid heating to test temperature as well as during slower temperature excursions associated with multi-step treatments have been characterized. Calibration procedures have been developed to allow direct calculation of ambient temperature resistivity from BCA voltage output during isothermal aging treatments and hardness data were correlated with the resistivity data. Sensors capable of operation at temperatures up to 230 C will also be fabricated.

THESIS DIRECTED:

B. James, "Sensor Calibration for Resistivity Determination during Isothermal Age Hardening of Aluminum Alloys," Master's Thesis, Naval Postgraduate School, March 1996

DoD KEY TECHNOLOGY AREAS: Materials, Processes and Structures

KEYWORDS: Intelligent processing, heat treating, aluminum alloys

OPERATIONAL AND TACTICAL EVALUATION OF SHALLOW WATER NEAR SURFACE SUBMARINE RESPONSE

F.A. Papoulias, Associate Professor
Department of Mechanical Engineering
Sponsors: Naval Surface Warfare Center-Carderock Division and Naval Postgraduate School

OBJECTIVE: The objective of this on-going project was to initiate efforts in characterizing and classifying both open loop and closed loop submarine near surface response, in forms that can be directly utilized during preliminary design phases.

SUMMARY: Submarine operations at periscope depth become increasingly important as new roles for the Navy in littoral waters are emerging. This requires applied research on several aspects of maneuvering and depth control of submarines and submersible vehicles in the proximity of a free surface. In this project several studies were conducted in order to classify and evaluate various vehicle response characteristics. A systematic series of parametric studies revealed the dependence of the operability window of a vehicle in terms of its operating speed and depth, as a function of fundamental geometric quantities characteristic of the vehicle geometrical shape. These studies were conducted in all sea state and sea heading of interest. In addition to open loop dynamics, the closed loop control behavior of the vehicle was analyzed by utilizing a variety of control strategies. The results were tabulated in terms of the overall control accuracy. This provides a systematic way for analyzing the performance of the control system, and establishes rational guidelines for sensor selection. Finally, an experimental program utilizing parametric studies and the use of the NPS autonomous underwater vehicle as a test-bed was developed and proposed.

PUBLICATION:

Papoulias, F.A., and Papnikolaou, S., "Parametrics of Submarine Dynamic Stability in the Vertical Plane," Proceedings of the ASME, OMAE '96, Florence, Italy.

THESES DIRECTED:

Papanikolaou, S., Hellenic Navy, "Parametric Studies of Dynamic Stability of Submersible Vehicles in the Vertical Plane," Master's Thesis, Naval Postgraduate School, March 1996.

Toprak, U., Turkish Navy, "Assessment of Shallow Water Near Surface Response of Submersible Vehicles," Master's Thesis, Naval Postgraduate School, June 1996.

Celikel, A. Kaan Turkish navy, "Parametrics of Near Surface Response of Submersible Vehicles," Master's Thesis, Naval Postgraduate School, September 1996.

Tolliver, John V. "Studies on Submarine Control for Periscope Depth Operations," Master's Thesis, Naval Postgraduate School, September 1996.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles - Ships and Watercraft

KEYWORDS: Submarine response, near surface, littoral waters

DYNAMICS OF DROP FORMATION

T. Sarpkaya, Distinguished Professor
Department of Mechanical Engineering
Sponsor: Office of Naval Research

OBJECTIVE: The ultimate objective of the investigation is to understand, model and predict droplet and spray formation from a sheet of water. The technological importance and intellectual challenge presented by this nontrivial flow phenomena demand a scientific understanding of its physics through judiciously conceived physical experiments and numerical analyses.

SUMMARY: The work carried out during the first year of the investigation may be summarized as follows: An extensive literature search has been carried out and experiments have been designed to understand the influence of several competing internal/external influences such as turbulence, gravity, surface tension, liquid-sheet geometry, surface shear, roughness of the contact surfaces, velocity distribution in the sheet, pressure fluctuations within and outside the liquid sheet, acoustic excitation, external flows (e.g., wind), intentionally imposed disturbances, and foreign particles in the sheet.

A two-dimensional nozzle was designed and attached to a large (existing) water tunnel through the use of four streamlined transition modules. The large reservoir and the recirculation of water served to maintain a steady water sheet at desired constant velocities. A laser-Doppler Velocimeter (LDV) has been used to obtain detailed velocity and turbulence measurements and laser-induced fluorescence (LIF) was used to delineate the formation of droplets and instability "spots" in thin water sheets bounded by a smooth flat plate and the free surface. An axisymmetric nozzle and a second two-dimensional nozzle have been designed and constructed to extend the limits of the parameter space. The investigation is part of an on-going Doctoral work, to be completed in December 1998.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles - Ships and Watercraft

KEYWORDS: Hydrodynamics, drop formation, spray

KELVIN/LIGHTHILL POTENTIAL AND VORTICITY DRAG DECOMPOSITION OF WAVE LOADING

T. Sarpkaya, Distinguished Professor
Department of Mechanical Engineering
Sponsor: Office of Naval Research

OBJECTIVE: The combined analytical, numerical, physical, and thought experiments address the old and difficult problem of devising a physics-based model for the prediction of flow-induced unsteady forces on bluff bodies immersed in time-dependent flows. The new model, based on a sounder scientific rational, is expected to replace Morison's equation and offer greater universality and higher engineering reliability, particularly in the so-called drag-inertia regime.

SUMMARY: The work carried out during the first year of the investigation may be summarized as follows: About one half of over 3,000 digital force-time-data files have been re-evaluated in order to separate the resistance for each combination of the Keulegan-Carpenter number Kc, Frequency parameter, the Reynolds number Re, and the relative roughness k_s/D into the sum of an inviscid inertial force and a vorticity-induced force. Several fundamental concepts for the modeling of the *vorticity-force* have been tried. Two of these are: (a) The use of a steady-state drag (function of Re and k_s/D only) plus a history-integral force (dependent on Re, k_s/D, and). Such a model was successful in the Stokes regime where the flow is unseparated. For separated flows, however, it did not turn out to be a meaningful approach because of the fact that the state of the steady flow (laminar or turbulent boundary layers) is dictated by circumstances significantly different from those in oscillating flows (wake return, etc.); and (b) The use of a velocity-square-dependent drag force (as in Morison's equation), an ideal inertial force (dependent on the theoretically-determined added mass coefficient), and a history term (dependent on the two coefficients just cited, including, of course, the parameters Kc and). After considerable effort, a new and relatively simple three-term force model has been devised. It does not require the introduction of new empirical coefficients and it does not deal with the transverse force. Extensive calculations for all values of Kc and (previously encountered by this investigator) have shown that the new model predicts the measured force with an error less than 10% in all ranges of the governing parameters.

PUBLICATIONS:

Sarpkaya, T., "Hydrodynamic Damping, Flow-Induced Oscillations, and Biharmonic Response," Journal of Offshore Mechanics and Arctic Engineering, TRANS. ASME, pp. 232-238 1996.

Sarpkaya, T., "Perspectives on Bluff Body Aerodynamics: Intellectual Challenges and Practical Applications," Proceedings of the International Conference on Bluff Body Aerodynamics & Applications-III, pp. 1-11, 1996.

Sarpkaya, T., "Unsteady Flows," Chapter 12, in Handbook of Fluid Dynamics and Fluid Machinery, (ed: J.A. Schetz), John Wiley & Sons, Vol. 1, pp. 697-732, 1996.

Sarpkaya, T., and Massidda, T., "Conductivity Measurements in the Wake of Submerged Bodies in Density-Stratified Media," Proceedings of the Twenty-First Symposium on Naval Hydrodynamics, Trondheim, Norway, Vol. 1, pp: 216-225, 1996..

Sarpkaya, T., and O'Keefe, J.L., "Oscillating Flow about Two- and Three-Dimensional Bilge Keels," Journal of Offshore Mechanics and Arctic Engineering, TRANS. ASME, pp. 1-6 1996.

Sarpkaya, T., de Angelis, M, and Hanson, C., "Oscillating Turbulent Flow with or without a Current about a Circular Cylinder," Proceedings of the International Conference on Offshore Mechanics and Arctic Engineering, Vol. I, Part A., pp. 353-360, 1996.

Sarpkaya, T., and Swean, T., Jr., "A Novel Equation for Resistance in Time-Dependent Flow," (to be published in the Proceedings of the 8th International Conference on the Behavior of Off-Shore Structures proceedings, July 1997).

Sarpkaya, T., de Angelis, M, and Hanson, C., "Oscillating Turbulent Flow with or without a Current about a Circular Cylinder," Journal of Offshore Mechanics and Arctic Engineering, TRANS. ASME, (in print, to appear in March 1997).

DoD KEY TECHNOLOGY AREAS: Other (Environmental Effects)

KEYWORDS: Bluff body, resistance, vorticity

AN EXPERIMENTAL AND NUMERICAL INVESTIGATION OF TURBULENT VORTEX BREAKDOWN AND AIRCRAFT WAKES

T. Sarpkaya, Distinguished Professor
Department of Mechanical Engineering
Sponsor: National Aeronautics and Space Administration, Office of Naval Research and Naval Postgraduate School

OBJECTIVE: A basic and applied research towards the understanding of the phenomena resulting from the breakdown of vortices in trailing vortices and in a turbulent flow field, created by a round swirling jet issuing from a nozzle, for various swirl ratios, Froude and Reynolds numbers, and deep and shallow modes, using a three-component LDV system and laser-induced flow visualization.

SUMMARY: The statistical as well as structural characteristics of the turbulent flow field resulting from the swirling turbulent flow in a pipe and the swirling jet in an unbounded medium were investigated in order to elucidate the physics of the phenomena relevant to the understanding of vortex breakdown and its numerical simulation. Turbulence intensities, energy spectra, and turbulent stresses were measured with an LDV. The results refute the conjectures that the circumstances of breakdown are insensitive to the Reynolds number and the local turbulence properties. These two factors appear to have a strong influence not only on the development of the swirling flow prior to its breakdown but also on its topology after the onset of breakdown as far the swirling flows in tubes and free swirling jets in an unbounded medium are concerned. If there is any hope of making realistic predictions of turbulent vortex breakdowns, the boundary conditions, in particular the velocity and turbulence profiles upstream of the breakdown, need to be known with great precision. Furthermore, if vortex breakdown is to be used to exploit its advantages, as in combustion, or to be avoided to escape its disadvantages, as in the case of delta wings, the experiments must quantify the conditions far upstream of the breakdown and the numerical calculations must adopt them as initial conditions. It is only then that it will be possible to assess the effect of often unknown upstream disturbances on the behavior of vortex breakdown. The investigation is part of an on-going Doctoral work, to be completed in December 1998.

PUBLICATIONS:

Feyedelem, M., and Sarpkaya, T., "Free and Near-Free-Surface Swirling Turbulent Jets," Journal of the American Institute of Aeronautics and Astronautics, (to appear in 1997).

Sarpkaya, T., "Interaction of Vorticity, Free-Surface, and Surfactants," Annual Review of Fluid Mechanics, Vol. 28, pp. 83-128, 1996.

Sarpkaya, T., "Vortices, Turbulence, Vortex Breakdown, and Free Surface," Proceedings of the ONR meeting on Free-Surface Turbulent Flows, February 1996.

Sarpkaya, T., and Massidda, T., "Conductivity Measurements in the Wake of Submerged Bodies in Density-Stratified Media," Proceedings of the Twenty-First Symposium on Naval Hydrodynamics, Trondheim, Norway, Vol. 1, pp: 216-225, 1996.

THESES DIRECTED:

Feyedelem, M.S., "Interaction of a Swirling Jet with a Free Surface," Master's and Mechanical Engineer's Thesis, Naval Postgraduate School, March 1996.

Thiele, C., "Vortex Breakdown at a Reynolds Number of 120,000," Master's Thesis, Naval Postgraduate School, March 1996.

DoD KEY TECHNOLOGY AREAS: Other (Environmental Effects)

KEYWORDS: Vortex breakdown, vorticity, swirling flow, free-surface

SHOCK AND VIBRATION RESEARCH IN SUPPORT OF ADVANCED LIGHTWEIGHT INFLUENCE SWEEP SYSTEM (ALISS)

Young S. Shin, Professor
Department of Mechanical Engineering
Sponsor: Naval Surface Warfare Center-Carderock Division

OBJECTIVE: The scientific objectives include: (1) to study the operational environment in which the ALISS must be designed to perform and to make a recommendation on shock and vibration design criteria, and (2) to investigate dynamic behavior of GE and GA superconductor models and to assess the survivability based on the proposed shock and vibration design criteria.

SUMMARY: This is a on-going shock and vibration research project in support of Advanced Lightweight Influence Sweep System (ALISS). ALISS is an Advanced Technology Demonstration (ATD) program to validate the feasibility of superconducting technology to sweep magnetic influence mines. A Superconducting Mine Countermeasures (SCMCM) system would be small, light, and simple compared to currently deployed MCM system. When ALISS is constructed as a superconducting mine countermeasure, the system must perform satisfactorily under the extremes of shock and vibration environment encountered in military applications. The task conducted include: (1) modal analysis and transient response analysis of _ scale GE and GA superconductor magnet SCMCM models and, (2) to assess the shock and vibration survivability of the system.

DoD KEY TECHNOLOGY AREAS: Materials, Processes and Structures

KEYWORDS: ALISS, superconducting mine countermeasures, Light Weight Influence Mine Sweep System, shock and vibration

DYNAMICS OF UNDERWATER EXPLOSION GAS BUBBLE AND ITS INTERACTION WITH BOUNDARY SURFACE

Young S. Shin, Professor
Department of Mechanical Engineering
Sponsor: Unfunded

OBJECTIVE: To investigate the modeling and simulation of underwater explosion gas bubble behavior, and its interaction with flexible boundary using Lagrangian-Eulerian finite element analysis approach.

SUMMARY: The numerical modeling and simulation of explosion gas bubble behavior in the compressible fluid medium were investigated. The effects of compressibility and gas energy on the dynamic behavior of an explosion gas bubble were investigated. The dynamic behavior of deep explosion gas bubble in the vicinity of plane rigid or constant pressure boundary was also investigated. In addition, the rigid boundary curvature effect on gas bubble oscillation was also studied.

PUBLICATIONS:

Chisum, J.E., and Shin, Y.S., "Explosion Gas Bubble Near Simple Boundaries," Accepted for Publication and to appear in Journal of Shock and Vibration.

Shin, Y.S., and Chisum, J.E., "Modeling and Simulation of Underwater Shock Problems Using a Coupled Lagrangian-Eulerian Analysis Approach," Accepted for Publication and to appear in Journal of Shock and Vibration.

Shin, Y.S., and Hooker, D.T., "Damage Response of Submerged Imperfect Cylindrical Structures To Underwater Explosion," Journal of Computer & Structures, Vol. 60, No. 5, pp. 683-693, 1996.

CONFERENCE PRESENTATIONS:

Shin, Y.S., and Chisum, J.E., "Modeling and Simulation of Underwater Shock Problems Using a Coupled Lagrangian-Eulerian Analysis Approach," Invited presentation at International Seminar on "Hydroelasticity in Ship Structural Design," CETENA Italian Ship Research Center, Genova, Italy, February 1996.

Shin, Y.S., and Masumoto, K., "Underwater Explosion Gas Bubble-Curved Boundary Interaction Analysis," Symposium on Structures under Extreme Loading Condition-1996, ASME Pressure Vessel and Piping Conference, Montreal, Quebec, Canada, July 1996.

THESES DIRECTED:

Matsumoto, K., "Boundary Curvature Effects on Gas Bubble Oscillations in Underwater Explosion," Master's Thesis, Naval Postgraduate School, March 1996.

Chisum, J.E., "Simulation of the Dynamic Behavior of Explosion Gas Bubbles in a Compressible Fluid Medium," Doctor of Philosophy in Mechanical Engineering, December 1996.

DoD KEY TECHNOLOGY AREAS: Environmental Quality

KEYWORDS: Underwater explosion, explosion gas bubble, Lagrangian-Eulerian analysis

SHOCK AND VIBRATION ANALYSIS IN SUPPORT OF DDG-51 CLASS SHOCK FOLLOW-ON ACTIONS

Young S. Shin, Professor
Department of Mechanical Engineering
Sponsor: Naval Sea Systems Command

OBJECTIVE: To perform shock and vibration analysis in support of DDG-51 Class shock follow-on actions including DDG-51 Flight IIA ship shock analysis to predict dynamic responses to underwater explosions. Also advanced data analysis method will be developed for DDG-51 Class ship shock survivability.

SUMMARY: The fluid-interaction and cavitation effects on a surface ship model due to an underwater explosion were investigated. DDG-51 Flight I was modeled using IGES model of Navy's ASSET program. It was investigated using USA-CFA-NASTRAN code.

CONFERENCE PRESENTATION:

Santiago, L.D., and Shin, Y.S., "Fluid-Interaction and Cavitation Effects on a Surface Ship Model due to an Underwater Explosion," 67th Shock and Vibration Symposium, Monterey, CA, November 1996

THESES DIRECTED:

Santiago, L.D., "Fluid-Interaction and Cavitation Effects on a Surface Ship Model due to an Underwater Explosion," Master's Thesis, Naval Postgraduate School, September 1996.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles - Ships and Watercraft, Modeling and Simulation

KEYWORDS: Surface Ship, underwater explosion, cavitation, fluid-structure interaction

AGE-RELIABILITY ANALYSIS OF SHIPBOARD REPAIRABLE SYSTEMS

Young S. Shin, Professor
Department of Mechanical Engineering
Sponsor: Naval Sea Systems Command

OBJECTIVE: The objective is to examine whether certain Class Maintenance Plan (CPM) tasks satisfy Reliability Centered Maintenance (RCM) criteria for applicability by examining the age-reliability characteristics of one or more of three different shipboard equipments: AOE-1 Class main feed pumps, AOE-1 Class electric-driven fire pumps and controllers, and FFG-7 Class high-pressure air compressors.

SUMMARY: The age reliability relationships must be determined for an effective and efficient Preventive Maintenance (PM) program. New preventive maintenance requirements must be based on Reliability Centered Maintenance (RCM) analysis as presented in MIL-STD-2173 (AS). A RCM analysis provides the reliability characteristics (mission reliability, probability of failure, age-reliability, etc.) on the equipment which may require age exploration. Ships' 3M data for the target equipment was obtained through the database maintained by Naval Sea Logistics Center. Five year database contained over 8,000 repair records per target equipment. The statistical analysis has been conducted to develop age-reliability curve for each equipment.

DoD KEY TECHNOLOGY AREAS: Materials, Processes and Structures

KEYWORDS: Age-reliability, ships' 3M data, repairable system

SURVIVABILITY OF SHIPBOARD PERSONNEL SUBJECTED TO HIGH AMPLITUDE, LOW FREQUENCY SHOCK INDUCED BY UNDERWATER EXPLOSION

Young S. Shin, Professor
Department of Mechanical Engineering
Sponsor: Naval Sea Systems Command

OBJECTIVE: Modeling and simulation of dynamic behavior of hybrid dummies mounted on the SSTV subjected to underwater explosion. The shock loading includes the high amplitude, low frequency shock. Subsequently the dynamic behavior of shipboard personnel (normal male and female) will be investigated from the standpoint of survivability and critical injuries.

SUMMARY: The Articulated Total Body (ATB) modeling approach was used to model the motion of a human (or test dummy such as the Hybrid III) in response to ship shock. The preliminary investigation was conducted to simulate the response such as the gross motion, the contact forces between body parts and the surrounding environment, the torque within the body's joints, and the relative accelerations of the body parts (head acceleration with respect to the upper torso, for example).

DoD KEY TECHNOLOGY AREAS: Materials, Processes and Structures

KEYWORDS: Underwater explosion, human survivability

EVALUATION OF ENVIRONMENTAL REQUIREMENT, TEST METHODS AND STANDARD FOR TACTICAL ADVANCED COMPUTERS: SHOCK, NOISE AND VIBRATION

Young S. Shin, Professor
Department of Mechanical Engineering
Sponsor: Naval Command, Control and Ocean Surveillance Center

OBJECTIVE: To review and evaluate the MILSPECS from the standpoints of shock and vibration for the survivability of racks, cabinets, enclosures and other components to be procured under TAC-5 (Tactical Advanced Computer Fifth Generation).

SUMMARY: The Navy has demonstrated a commitment to migrating highly customized automation requirements in tactical systems to approaches exploiting the use of commercial-based technologies and Commercial-Off-The-Shelf (COTS) components as part of the TAC-5. However, the survivability of COTS in various types of severe environments is questionable. The evaluation results showed that the recent commercially available products such as high performance processors, low cost workstations, fully populated 72" and 60" racks may meet the code requirement for airborne noise, structureborne noise, storage and transportation shock, and ship motion and attitude. However, the COTS may not survive for severe shock and vibration environments.

DoD KEY TECHNOLOGY AREAS: Environmental Quality

KEYWORDS: Shock and vibration, TAC-5, computers

PUBLICATIONS/PRESENTATIONS

JOURNAL PAPERS

Fox, A.G., Eakes, M.W., and Franke, G.L. "The Effect of Small Changes in Flux Basicity on the Acicular Ferrite Content and Mechanical Properties of Submerged-Arc Weld Metal of Navy HY-100 Steel," Welding Journal Research Supplement, Vol. 75, 330s-342s 1996.

Gordis, J.H., "On the Analytic Disassembly of Structural Matrices," Modal Analysis, Vol. 11, No. 1-2, pp. 39-48 1996.

Gordis, J.H., "Omitted Coordinate Systems and Artificial Constraints in Spatially Incomplete Identification," Modal Analysis, Vol. 11, No. 1-2, pp. 83-95 1996.

Kwon, Y.W., and Aygunes, H., "Dynamic Finite Element Analysis of Laminated Beams With Delamination Cracks Using Contact-Impact Conditions," Computers and Structures, Vol. 58, No. 6 1996, pp. 1161-1169.

Marco, D.B., Healey, A.J., and McGhee, R.B., "Autonomous Underwater Vehicles: Hybrid Control of Mission and Motion," Journal of Autonomous Robots, Special Issue on Autonomous Underwater Robots, 3,169-186 1996.

McNelley, T.R., and McMahon, M.E., "Analyzing Superplastic Microstructures Using Interactive EBSP Methods," Journal of the Minerals, Metals and Materials Society, 48, No. 2, p. 58, February 1996.

McNelley, T.R., and McMahon, M.E., "An Investigation by Interactive EBSP Analysis of Processing and Superplasticity in an Aluminum-Magnesium Alloy," Metallurgical and Materials Transactions A, 27A 1996, p. 2252.

Menon, E.S.K., and Dutta, I., "A Surface Treatment of CVD Diamond Substrates for Producing Adherent Metallizations," Appl. Physic. Letter., 68 p. 2951 1996.

Menon, E.S.K., Fox, A.G., and Mahapatra, R. "Accurate Determination of Lattice Parameters of TiAl Alloys," Journal of Materials Science Letters, Vol. 15, pp. 1231-1233 1996.

Sarpkaya, T., and O'Keefe, J.L., "Oscillating Flow about Two-and Three-Dimensional Bilge Keels," Journal of Offshore Mechanics and Arctic Engineering, TRANS. ASME, pp. 1-6 1996,.

Sarpkaya, T., "Interaction of Vorticity, Free-Surface, and Surfactants," Annual Review of Fluid Mechanics, Vol. 28, pp. 83-128 1996.

Sarpkaya, T., "Hydrodynamic Damping, Flow-Induced Oscillations, and Biharmonic Response," Journal of Offshore Mechanics and Arctic Engineering, TRANS. ASME, pp. 232-238 1996.

Shin, Y.S., and Hooker, D.T., "Damage Response of Submerged Imperfect Cylindrical Structures To Underwater Explosion," Journal of Computer & Structures, Vol. 60, No. 5, pp. 683-693 1996.

CONFERENCE PAPERS

An, P.E., Healey, A.J. Smith, S.M., and Dunn, S.E., "New Results on GPS / INS Navigation for Ocean Voyager II AUV," Proceedings of the 1996 IEEE Symposium on Autonomous Underwater Vehicle Technology, pp. 249-256, Monterey, CA, 2-6 June 1996

Bachmann, E.R., McGhee, R.B., et. al., "Evaluation of an Integrated GPS / INS System for Shallow Water AUV Navigation (SANS)," Proceedings of the 1996 IEEE Symposium on Autonomous Underwater Vehicle Technology, pp. 268-276, Monterey, CA, 2-6 June 1996.

PUBLICATIONS/PRESENTATIONS

Brutzman, D., Burns, M., et al., "NPS Phoenix AUV Software Integration and In water Testing," Proceedings of the 1996 IEEE Symposium on Autonomous Underwater Vehicle Technology, pp. 99-109, Monterey, CA, 2-6 June 1996.

Dutta, I., and Derby, B., "An Analytical Treatment for the Determination of Time-Dependent High Temperature Interface Properties in Metal-Matrix Composites via Fiber-Pushout Tests," 1996 TMS Fall Meeting, October 1996.

Fox, A.G., Kumar, A., and Menon, E.S.K. "Electron Spectroscopic Imaging of Interfaces in a Nicalon (Si-C-O) Fiber-Reinforced Glass-Ceramic Matrix Composite," Proceedings of the Recent Advancement of Interfacial Materials Science on Composite Materials '96 Conference, Kyushu University, Japan, May 1996.

Fox, A.G., and Menon, E.S.K. "Measurement of the Debye-Waller Factors of Elements and Binary Compounds by Convergent Beam Electron Diffraction," Proceedings of Eurem '96, Dublin, Eire, August 1996.

Fox, A.G., Eakes, M.W., and Wong, R.J. "The Effect of Cover Gas Composition on the Microstructure and Mechanical Properties of Gas-Metal-Arc Weld Metal of Navy HSLA-100 Steel," Proceedings of the Joining of Advanced Materials, an International Conference on Advances in Welding Technology sponsored by EWI, Columbus, OH, November 1996.

Gopinath, A., "Thermoacoustic Effects at a Solid-Fluid Boundary: The Role of a Second Order Thermal Expansion Coefficient," Third Microgravity Fluid Physics Conference, Cleveland, OH, June 1996, NASA Conference Publication 3338, pp. 661-666 1996.

Gopinath, A., "Acoustic Streaming in a Resonant Channel," 131st Meeting of the Acoustical Society of America, Indianapolis, IN, May 1996, Abstract in Journal of the Acoustical Society of America, Vol. 99, No. 4, Pt. 2, p. 2540, April 1996.

Gopinath, A., Harder, D.R., and Bridenstine, M., "Convective Heat Transfer from a Cylinder in a Resonant Acoustic Field," 3rd Joint Meeting of the Acoustical Society of America and the Acoustical Society of Japan, Honolulu, HI, December 1996, Abstract in Journal of the Acoustical Society of America, Vol. 100, No. 4, Pt. 2, p. 2847, October 1996.

Gordis, J.H., "Artificial Boundary Conditions for Model Updating and Damage Detection," Proceedings of the 1996 Shock and Vibration Symposium, Monterey, CA, 1996.

Gordis, J.H., "On the Analytic Disassembly of Structural Matrices," Proceedings of the 1996 Shock and Vibration Symposium, Monterey, CA, 1996.

Healey, A.J., Kim, J., and Lewis, T., "Control of Small Robotic Vehicles In Unexploded Ordnance Clearance," Proceedings of the Symposium on Autonomous Vehicles in Mine Countermeasures, Naval Postgraduate School, November 1996.

Healey, A.J., and Marco, D.B., "A Trilevel Control System for Coordination of Control Modes of AUVs," Proceedings of Noise Con 96, pp. 363-368, Seattle WA, September 1996.

Healey, A.J., Marco, D.B., et. al., "Strategic Level Mission Control-An Evaluation of CORAL and PROLOG Implementation for Mission Control Specifications," Proceedings of the 1996 IEEE Symposium on Autonomous Underwater Vehicle Technology, pp. 125-135, Monterey, CA, 2-6 June 1996.

Healey, A.J., Marco, D.B., McGhee, R.B., "Autonomous Underwater Vehicle Control Coordination Using A Tri-Level Hybrid Software Architecture," Proceedings of the IEEE Robotics and Automation Conference, Minneapolis, MN, April 1996.

PUBLICATIONS/PRESENTATIONS

Knowles K.M., Kumar A., and Fox A.G., "Microstructural Characterization of As-Processed and Oxidized Si-C-O Fibre-Reinforced Barium Magnesium Aluminosilicates," Proceedings of Microscopy of Oxidation III Conference, Cambridge, U.K., September 1996.

Kumar A., Fox, A.G., and Wang, S.W., "Mechanisms of Hot Corrosion of a SiC Fiber-Reinforced Glass Ceramic," Proceedings of the American Ceramic Society Conference, Cocoa Beach, FL, January 1996.

Kwon, Y.W., Lee, J.H., and Liu, C.T., "Modeling and Simulation of Crack Initiation and Growth in Particulate Composites," Recent Advances in Solids/ Structures and Application of Metallic Materials, PVP-Vol. 342/MD-Vol. 72, American Society of Mechanical Engineers 1996.

Kwon, Y.W., Lee, J.H., and Liu, C.T., "Initial Damage and Crack in Particulate Composites," Proceedings of Third International Conference on Composites Engineering, New Orleans, LA, 21-26 July 1996.

Kwon, Y.W., and Kim, C., "Progressive Damage Evaluation of Composite Structures Using Micro/Macromechanics and Damage Mechanics," Proceedings of 14th U.S. Army Symposium on Solid Mechanics, Myrtle Beach, SC, 16-18 October 1996.

Marco, D.B., and Healey, A.J., "Local Area Navigation Using Sonar Feature Extraction and Model Based Predictive Control," Proceedings of the 1996 IEEE Symposium on Autonomous Underwater Vehicle Technology, 2-6 June1996, Monterey, CA, pp. 67-78.

Marco, D.B., Healey, A.J., and McGhee, R.B., "Hybrid Control Architecture Applied to an Autonomous Underwater Vehicle with Experimental Validation," By invitation only to NSF Sponsored Workshop "Advances in Subsea Robotics," IARP 1996, Toulon, France, March 1996

Millsaps, K.T., Simei, F.A., "Experimental Observations of Rotor Vibration in Subcritical/Supercritical Operation, Including Backward Whirl,". ISOROMAC-6, 24-28 February 1996, Honolulu, HI.

Millsaps, K.T., and Vejvoda, C.E., "Origin of Split Resonance and Backward Whirl in a Simple Rotor," IGTC, Birmingham, U.K., 6-10 June 1996.

Papoulias, F.A., and Papnikolaou, S. Parametrics of Submarine Dynamic Stability in the Vertical Plane, Proceedings of the ASME, OMAE '96, Florence, Italy.

Radwick J.L., Florence, D.E., and Gordis, J.H. "Optimal Design of One and Two-Layer Isolation Systems for Shock and Vibration," Proceedings of the 67th Shock and Vibration Symposium, Vol. 1, pp. 457-468, Monterey, CA, 18-22 November 1996.

Sarpkaya, T., "Perspectives on Bluff Body Aerodynamics: Intellectual Challenges and Practical Applications," Proceedings of the International Conference on Bluff Body Aerodynamics & Applications-III, pp. 1-11, 1996.

Sarpkaya, T., "Vortices, Turbulence, Vortex Breakdown, and Free Surface," Proceedings of the ONR meeting on Free-Surface Turbulent Flows, February 1996.

Sarpkaya, T., de Angelis, M, and Hanson, C., "Oscillating Turbulent Flow with or without a Current about a Circular Cylinder," Proceedings of the International Conference on Offshore Mechanics and Arctic Engineering , Vol. 1, Part A., pp. 353-360, June 1996.

Sarpkaya, T., and Massidda, T., "Conductivity Measurements in the Wake of Submerged Bodies in Density-Stratified Media," Proceedings of the Twenty-First Symposium on Naval Hydrodynamics, Vol. 1, pp. 216-225 1996.

PUBLICATIONS/PRESENTATIONS

Saunders, M., Midgley, P.A., Walsh, T.D., Menon, E.S.K., Fox, A.G., and Vincent, R. "Quantitative Energy-Filtered CBED-Matching Theory to Experiment," Proceedings of the 15th Pfefferkorn Conference, Silver Bay, NY, May 1996.

Shin, Y.S., and Zukas, J., "Structures under Extreme Loading Conditions-1996," ASME PVP-Vol. 325 1996 ASME PVP Conference, July 1996.

Stoker, C.R., Barch, D., Farmer, J., Flagg, M., Healey, A.J., Tengin, T., Thomas, H., and Scewer, K., "Exploration of Mono Lake with an ROV: A Prototype Experiment for the MAPS AUV Program," Proceedings of the 1996 IEEE Symposium on Autonomous Underwater Vehicle Technology, pp. 33-41, Monterey, CA, 2-6 June1996.

Trinh, E.H., and Gopinath, A., "Acoustic Streaming and Heat and Mass Transfer Enhancement," Third Microgravity Fluid Physics Conference, Cleveland, Ohio, June 1996, NASA Conference Publication 3338, pp. 791-796 1996.

Young, S.H., and Kwon, Y.W., "An Optimization Technique Using the Finite Element Method and Orthogonal Arrays," Recent Advances in Solids/ Structures and Application of Metallic Materials, PVP-Vol. 342/MD-Vol. 72, American Society of Mechanical Engineers 1996.

CONFERENCE PRESENTATIONS:

Adkison, D., DeMaio, M, and Kwon, Y., "Knee Kinematics in Four, Five, and Six-Degree of Freedom Models: More Constraint Causes Loss of Rollback and Rotation," Thirty-Eighth Annual Meeting of Society of Military Orthopaedic Surgeons, San Diego, CA, 19-23 November 1996.

Calvano, Charles N., "Comments on Total Ship Systems Engineering in a Combat Systems Environment," American Society of Naval Engineers Combat Systems Symposium, December 1996.

Calvano, Charles N., "Systems Engineering in a Ship Design Environment," One-day workshop seminar for American Society of Naval Engineers, Washington, DC, April 1996.

DeMaio, M., Adkison, D.P., and Kwon, Y.W., "Continuous Motion Kinematics of the Loaded Human Cadaveric Knee: The Effect of Cruciate Ligament Transection," 2nd World Congress on Sports Trauma/22nd Annual Meeting of the American Orthopaedic Society for Sports Medicine, Orlando, FL, 16-20 June 1996.

Driels, Morris, "Integrated Target Acquisition Planning Model," Air-to-Surface Working Group Meeting, Eglin AFB, FL, April 1996.

Driels, Morris, "Integrated Target Acquisition Planning Model," Air-to-Surface Working Group Meeting, Eglin AFB, FL, October 1996.

Driels, Morris, "Target Acquisition Overview," JMEM A/S Operational Users Working Group Meeting, NAS Miramar, CA, March 1996.

Dutta, I., and McNelley, T.R., "An Investigation of the Effect of Post-Fabrication Processing on Microstructure and Properties of a SiC_p-6092 Al Composite," 125th Annual Meeting of TMS, Anaheim, CA, 6 February 1996

Galvin, E., Demaio, M., Adkison, D.P., Kwon, Y.W., and Romero, N., "Continuous Motion Kinematics of the Unconstrained Human Cadaveric Knee. A Comparison of PCL-Retaining and PCL-Sacrificing Total Knee Replacements," Western Orthopaedic Association Meeting, January 1996.

PUBLICATIONS/PRESENTATIONS

Gopinath, A., "Acoustic Streaming in a Resonant Channel," 131st Meeting of the Acoustical Society of America, Indianapolis, IN, May 1996.

Gopinath, A., "Thermoacoustic Effects at a Solid-Fluid Boundary: The Role of a Second Order Thermal Expansion Coefficient," Third Microgravity Fluid Physics Conference, Cleveland, OH, June 1996.

Gopinath, A., Harder, D.R., and Bridenstine, M., "Convective Heat Transfer from a Cylinder in a Resonant Acoustic Field," 3rd Joint Meeting of the Acoustical Society of America and the Acoustical Society of Japan, Honolulu, HI, December 1996.

Kwon, Y.W., Lee, J.H., and Liu, C.T., "Initial Damage and Crack in Particulate Composites," Third International Conference on Composites Engineering, New Orleans, LA, 21-26 July 1996.

Kwon, Y.W., and Kim, C., "Progressive Damage Evaluation of Composite Structures Using Micro/Macromechanics and Damage Mechanics," 14th U.S. Army Symposium on Solid Mechanics, Myrtle Beach, SC, 16-18 October 1996.

Kwon, Y.W., Lee, J.H., and Liu, C.T., "Modeling and Simulation of Crack Initiation and Growth in Particulate Composites," ASME International Mechanical Engineering Congress and Exposition, Atlanta, GA, 17-22 November 1996.

McNelley, T.R., and McMahon, M.E., "Application of EBSP Analysis Methods to Distinguish Mesotexture in Superplastic Aluminum-Magnesium Alloys," Sixth Annual Conference: Frontiers of Electron Microscopy in Materials Science, Oak Park, IL, 6 June 1996

McNelley, T.R., Ballou, M.A., and Dutta, I., "A Microstructural Investigation of Particle Redistribution during Thermomechanical Processing of a Cast 6061 Al - Al_2O_3 MMC," Fall Meeting of ASM and TMS, Cincinnati, OH, 8 October 1996

McNelley, T.R., McMahon, M.E., and Hales, S.J., "Grain Boundary Development during Processing of Superplastic Aluminum Alloys," ReX'96: Third International Conference on Recrystallization and Related Phenomena, Monterey, CA, 23 October 1996

Menon, E.S.K., Kumar, A., Dutta, I., and Fox, A.G "Elemental Distributions Near Interfaces-Experimental Studies," presented at TMS Fall Meeting, Cincinnati, OH, October 1996.

Millsaps, K.T., and Simei, F.A., "Experimental Observations of Rotor Vibration in Subcritical/Supercritical Operation, Including Backward Whirl," ISOROMAC-6, Honolulu, HI, 24-28 February1996.

Millsaps, K.T., and Vejvoda, C.E., "Origin of Split Resonance and Backward Whirl in a Simple Rotor," IGTI, Birmingham, U.K. 1996.

Platzer, M., and Millsaps, K.T., "Gas Turbine Education at the Naval Postgraduate School," Invited Lecture at the IGTC, , Birmingham, U.K., 6-10 June 1996.

Santiago, L.D., and Shin, Y.S., "Fluid-Interaction and Cavitation Effects on a Surface Ship Model due to an Underwater Explosion," 67th Shock and Vibration Symposium, Monterey, CA, November 1996

Sarpkaya, T. (Invited Lecture), "Perspectives on Bluff Body Aerodynamics: Intellectual Challenges and Practical Applications," The International Conference on Bluff Body Aerodynamics & Applications-III, Blacksburg, VA, August 1996.

PUBLICATIONS/PRESENTATIONS

Sarpkaya, T., "Oscillating Turbulent Flow with or without a Current about a Circular Cylinder," The International Conference on Offshore Mechanics and Arctic Engineering , Florence, Italy, June 1996.

Sarpkaya, T., "Vortices, Turbulence, Vortex Breakdown, and Free Surface," The ONR meeting on Free-Surface Turbulent Flows, CALTECH, Pasadena, CA, February 1996.

Sarpkaya, T., de Angelis, M, and Hanson, C., "Oscillating Turbulent Flow with or without a Current about a Circular Cylinder," The International Conference on Offshore Mechanics and Arctic Engineering, Florence, Italy, June 1996.

Sarpkaya, T., and Massidda, T., "Conductivity Measurements in the Wake of Submerged Bodies in Density-Stratified Media," The Twenty-First Symposium on Naval Hydrodynamics, Trondheim, Norway, June 1996

Shin, Y.S., and Chisum, J.E., "Modeling and Simulation of Underwater Shock Problems Using a Coupled Lagrangian-Eulerian Analysis Approach," Invited presentation at International Seminar on "Hydroelasticity in Ship Structural Design," CETENA Italian Ship Research Center, Genova, Italy, February 1996.

Shin, Y.S., and Masumoto, K., "Underwater Explosion Gas Bubble-Curved Boundary Interaction Analysis," Symposium on Structures under Extreme Loading Condition-1996, ASME Pressure Vessel and Piping Conference, Montreal, Quebec, Canada, July 1996.

Shin, Y.S., "Overview of Underwater Shock and DDAM," 3-hour long Tutorial lectures, 67th Shock and Vibration Symposium, Monterey, CA, November 1996.

Trinh, E.H., and Gopinath, A., "Acoustic Streaming and Heat and Mass Transfer Enhancement," Third Microgravity Fluid Physics Conference, Cleveland, OH, June 1996.

Young, S.H., and Kwon, Y.W., "An Optimization Technique Using the Finite Element Method and Orthogonal Arrays," ASME International Mechanical Engineering Congress and Exposition, Atlanta, GA, 17-22 November 1996.

BOOKS

Driels, Morris, Handbook of Target Acquisition Models, Release 1.0, Tradoc Analysis Command, White Sands, NM, October 1996.

Kwon, Y.W., and Bang, H., The Finite Element Method Using MATLAB, CRC Press, Inc., Boca Raton, FL 1997.

CONTRIBUTIONS TO BOOKS

Sarpkaya, T., (1996), "Unsteady Flows," Chapter 12, in Handbook of Fluid Dynamics and Fluid Machinery, (ed: J.A. Schetz), John Wiley & Sons, Vol. 1, pp. 697-732.

PATENTS

Millsaps, K.T., Patent Disclosure, "Integrated Electric Gas Turbine," October 1996.

PUBLICATIONS/PRESENTATIONS

TECHNICAL REPORTS

Cunningham, R.E., and Kwon, Y.W., "Simplified Finite Element Modeling of Stiffened Cylinders Subjected to Underwater Explosion," NPS Report NPS-ME-96-002.

Van Court, R.R., and Kwon, Y.W., "Numerical and Experimental Study of Failure of the Human Proximal Femur," NPS Report NPS-ME-96-003.

OTHER

Gopinath, A., and Sadhal, S.S., eds. "Heat Transfer in Microgravity Systems," ASME-HTD-332, ASME International Mechanical Engineering Congress & Exposition, Atlanta, GA, November 1996.

Millsaps, K.T., "ICR Design Report-U.S. Navy Experience with Acid Condensation in Gas Turbine Exhaust Systems," September 16 1996.

Millsaps, K.T., "Rotordynamic Instability Boundaries of a Cryogenic Fuel Pump for a High Performance Rocket Engine," ROC-96-01023, May 1996.

Millsaps, K.T., and Shavit, A., "Analysis of Helium Injection into a Rankine Cycle," EPRI Final Report on CR-4CH9001, June 1996.

TOTAL SHIP INTEGRATION OF A FREE ELECTRON LASER (FEL)

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High-power Free Electron Lasers (FELs), capable of stopping an incoming anti-ship missile, can be an effective addition to the self-defense system of a modern naval combatant. A shipboard FEL must be compact, efficient, and capable of reliable operation in a naval environment. This thesis explores the feasibility of integrating a 1 MW infrared FEL aboard a surface combatant from a Total Ship Systems perspective. A study of system aspects including prime power systems and vibrational effects will be addressed to determine the overall ship impact.

A 1 MW FEL requires about 10 MW of electrical power from the shipboard prime power system if run continuously or approximately 2 MW using energy storage. A DDG-51 Arleigh Burke class Destroyer has sufficient reserve generating capacity to produce the required electrical power for the FEL. The required prime power electrical distribution system is compatible with the ship's main propulsion gas turbines and will weigh 42900 kg and occupy 35 m^3. Shipboard vibrations which will have the greatest influence on the FEL are generally characterized at frequencies below 50 Hz and have amplitudes approaching 900μm. The effect of these vibrations can reduce to an acceptable level which will permit continuous operation in the maritime environment. From a Total Ship Systems perspective the FEL can be accommodated in a DDG-51 class destroyer with negligible impact.

THE EFFECT OF THERMOMECHANICAL PROCESSING ON THE TENSILE PROPERTIES AND MICROSTRUCTURE OF A 6061 AL-AL_2O_3 METAL MATRIX COMPOSITE

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This work includes a comprehensive analysis of the effect of thermomechanical processing (TMP) history on the microstructure and properties of 10 and 20 volume percent 6061 Al-Al_2O_3 discontinuous metal matrix composites (MMCs). Materials in which cold drawing and annealing operations were included in the TMP demonstrated increased ductilities for a given strength level when compared to materials which were processed by hot extrusion only. Microstructural analysis provided clear evidence of the absence of damage to reinforcing particles during TMP and of load transfer to these particles during subsequent straining. Failure during tension testing resulted from the ductile tearing of the matrix as voids, initiated by the cracking of reinforcement particles, joined together. A distinct microstructural difference related to processing history was the development of a strongly fibered particle distribution in materials experiencing low temperature drawing operations. In order to conduct an analysis of the mechanisms by which the particles are redistributed and reoriented during processing, a channel compression die was constructed which allowed processing to be simulated by compressive straining on a mechanical testing machine. This allowed careful control of the processing parameters. An analysis of the effects of processing temperature on particle redistribution and reorientation was conducted.

ASSESSMENT OF DIESEL ENGINE CONDITION USING TIME RESOLVED MEASUREMENTS AND SIGNAL PROCESSING

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An experimental investigation was conducted to access methods of detecting, and localizing faults in a diesel engine. A three cylinder, two stroke Detroit 3-53 engine was heavily instrumented for time resolved measurements. In particu-

lar, a 3,600 count per revolution optical encoder was used along with accelerometers mounted on various engine structures, in-cylinder pressure measurements and a variety of steady state sensors, such as exhaust temperatures. A large number of baseline data were taken to establish the statistical characteristics on the signals from the engine. These runs were followed by a series of experiments where the cylinder head assembly bolt torque were varied parametrically. Standard spectral analysis and Joint Time Frequency Analysis (JTFA) were used to identify the fundamental vibration characteristics of the engine. The vibration frequencies were checked for consistency against first order models of the engine assembly and reasonable agreement was found. In addition, a new technique for accessing engine health using time of arrival of encoder signals was investigated.

THE ROLE OF PARTICLE CRACKING IN DILATATION DURING TENSILE STRAINING OF A CAST AND THERMOMECHANICALLY PROCESSED 6061 AL-20 VOLUME PERCENT AL_2O_3 METAL MATRIX COMPOSITE

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In this work, the dilatation during tensile straining of a cast and thermomechanically processed 6061 Al- Al_2O_3 metal matrix composite (MMC) containing 20 volume percent of Al_2O_3 particles was examined.

Standard tensile test samples of the MMC and unreinforced 6061 Al were machined. Precise diameter measurements were made of both composite and unreinforced samples prior to and immediately following tensile straining. Tension tests were conducted to various strains as well as to fracture and an extensometer was employed to obtain accurate measurement of the axial strain. The MMC material exhibited a continuously increasing dilatation during tensile straining while the unreinforced 6061 control material deformed plastically at constant volume.

Careful metallographic preparation revealed particle cracking in all MMC samples throughout the range of strains examined. A clear trend of increased frequency of particle cracking was observed. Void formation and growth due to cracking of the particles was analyzed and shown to correlate with the dilation observed during tensile straining of the composite. Linkage of such voids is proposed as the mechanism of crack propagation at failure of the MMC.

CONVECTIVE HEAT TRANSFER FROM A VERTICAL CYLINDER IN A HIGH AMPLITUDE RESONANT SOUND FIELD

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This thesis is part of a continuing study in developing convective heat transfer correlation's for a cylinder in a high amplitude zero-mean oscillating flow. The experiment described here utilizes the RTD technique and a steady state heat transfer measurement method with a platinum wire, serving as the test section, positioned across the inner diameter of a cylindrical Plexiglas chamber supporting a strong resonant axial acoustic field. Utilizing two different wire diameters of 0.050 mm and 0.127 mm, various pressure ratios, frequencies, and temperature differences, separated flow heat transfer correlations have been developed. This work would find application in the design of heat exchangers for a thermo-acoustic engine.

TRADEOFF ANALYSIS MODEL FOR ARSENAL SHIP SURVIVABILITY AND SUSTAINABILITY

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The arsenal ship program is unique and requires examining the possible features of a paradigm shift in ship design. This thesis presents a user-friendly model with which a decision maker can perform tradeoff analyses between adding specific systems and technologies to the arsenal ship or adding the escort services of combatant ships. The goal of the model is to produce configuration alternatives with high arsenal ship survivability subject to a budget constraint. The model also examines operational logistics by predicting the sustainability of forces with specified arsenal ship configurations. As some inputs are necessarily speculative at this stage, the model is formatted parametrically to facilitate easy updating. A balanced arsenal ship design incorporating point defense, stealth, and hardening is the most attractive choice for littoral operations when life cycle costs are considered. The naval component must also be balanced, reinforcing the notion that stealth and staying power are important in an arsenal ship task force containing DDG-51s and SC-21s.

PARALLEL IMPLEMENTATIONS OF PERSPECTIVE VIEW GENERATOR RAY TRACING ALGORITHMS

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In developing line of sight target acquisition software two approaches have been explored. The first was an object based system (Young and Whitney). Next, and more recently, has been the implementation of a database driven simulation. The heart of this implementation is the Perspective View Generator (PVG) developed for the U.S. Army by Wolfgang Baer. This implementation suffers from two fundamental shortcomings: low frame rates and unrealistic representation of target vehicles. This paper concentrates on using more powerful, multi-processor work stations to improve frame rates. The paper also addresses possible methods for representing vehicles in this multi-processor environment.

PARAMETRICS OF NEAR SURFACE RESPONSE OF SUBMERSIBLE VEHICLES

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Vertical plane response of submersible vehicles in the proximity of a free surface in deep water is evaluated using a potential flow, strip theory solver. Two criteria, that are periscope submergence, and sail broaching are used to quantify the response. These criteria combined with the vehicle's response amplitude operators in regular sinusoidal waves along with a statistical description of the seaway lead to an assessment of an overall operability index for the vehicle. This thesis presents a systematic parametric study of the effects of body geometry on near surface response. Two cases, namely limited diameter and limited length are considered. The total volume of the vehicle is kept constant, and certain shape factors are changed, while either the overall diameter or the overall length remains the same. The operability

index is calculated for each case within a given range for sea states and sea directions and for various shape factors, vehicle speeds and operating depths. The results indicate that certain changes of shape factors can improve vehicle operations in various depth and speed combinations.

THE EFFECT OF VARYING THE MnO CONTENT OF THE FLUX USED FOR THE SUBMERGED ARC WELDING OF NAVY HY-100 STEEL

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Weld metal strength and toughness are determined by its microstructure, which is in turn determined by the concentration of various alloying elements and impurities as well as the welding thermal cycle. This study investigated the effects of systematically varying the manganese oxide content in the flux used for HY-100 submerged arc welds. A trial addition of cerium oxide was also performed. Specimens were compared using mechanical properties, weld metal chemistry, inclusion chemistry, and microstructural analysis. It was found that cerium oxide addition and the correct amount of manganese oxide resulted in improved toughness. These improved properties were determined to arise from a low proportion of bainite in the fully reaustenitized region of the weld metal HAZ in these multipass welds. In the MnO series welds, the bainite is replaced by a fine low carbon martensite due to the increased weld metal hardenability. In the CeO_2 weld it is replaced by acicular ferrite due to the lowering of the austenite grain boundary energy by the cerium. The production of a series of welds with different manganese contents also resulted in the extension of existing theories of weld metal deoxidation.

COMPARATIVE DESIGN ANALYSIS OF A FUEL CELL POWERED COAST GUARD CUTTER

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This investigation studied the impact of using fuel cells as the primary power source in a ship design. Three different fuel cells were modeled: Phosphoric Acid, Proton Exchange Membrane, and Molten Carbonate. These models were compared against a baseline design containing a more conventional power plant. The models were built and optimized using the "Advanced Surface Ship Evaluation Tool" (ASSET/MONOSC). Specifically, payload, endurance, sustained speed, and hull depth were held constant, while length, beam, and draft were optimized to provide a balanced design. Full load displacement and required fuel load were compared against the baseline values. Conclusions concerning the potential value of a fuel cell power plant were drawn.

ANALYTICAL ANALYSIS OF TIP TRAVEL IN A BOURDON TUBE

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Bourdon tubes are the most commonly used elastic elements in mechanical pressure gauges. Basic theory describing the principles of Bourdon behavior is readily available but very few analytical studies have been published that model Bourdon element behavior. The purpose of this research is to develop an analytical model to determine tip displacement in tubular elastic elements using basic principles of solid mechanics. To determine the validity of the results

obtained from the analytical model, a study of results from finite element solutions and experimental data is also present.

SIMPLIFIED FINITE ELEMENT MODELING OF STIFFENED CYLINDERS SUBJECTED TO UNDERWATER EXPLOSION
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Master of Science in Mechanical Engineering-March 1996
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Simplified finite element modeling of a stiffened cylinder subjected to underwater explosion was investigated. The use of smearing the stiffeners into the base structure as well as beam modeling using SOR (Surface of Revolution) beam elements were used in the model simplification process. The dynamic response and overall global deformation were then compared between the fully discretized stiffened cylinder model and the simplified models. The study first examined the effectiveness of smearing stiffeners into a flat plate. The smearing of stiffeners into a cylindrical shell orthotropically was then examined. Next, beam modeling of both unstiffened and stiffened cylinders was investigated. Finally an integrated beam/shell model of a stiffened cylinder was developed. These models were subjected to the same underwater explosive loading for numerical study. The analysis showed that when comparing the dynamic responses caused by underwater explosions between the discrete model, the beam model, and the beam/shell model of a stiffened cylinder, globally similar results could be produced.

WAVE/CURRENT INDUCED FORCES ON CIRCULAR CYLINDERS
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Master of Science in Mechanical Engineering-December 1995
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The numerical simulations of oscillating plus mean flow past a circular cylinder have been carried out in detail through the use of a commercially available software produced by CFDRC, running on a Silicon Graphics Inc. Indigo 2 Extreme computer. The Reynolds number, Keulegan-Carpenter number, and relative current velocity were systematically varied. Sensitivity analysis was performed to delineate the effects of time step, turbulence model and numerical schemes. The results have been compared to those obtained experimentally and to those predicted by the Morison Equation. In many cases the predicted force coefficients have shown good agreement with those obtained experimentally.

INTERACTION OF A SWIRLING JET WITH A FREE SURFACE
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Master of Science in Mechanical Engineering-March 1996
Mechanical Engineer-March 1996
Advisor: Turgut Sarpkaya, Department of Mechanical Engineering

The turbulent flow field of a swirling jet issuing from a nozzle, beneath and parallel to a free surface has been studied in as much detail as possible using a three-component laser Doppler velocimeter and flow visualization. The results have shown that the swirl leads to the faster spreading and quicker mixing of the jet. For strongly swirling jets (S = 0.522), the similarity is not reached within ten diameters downstream. The results have also shown that both the axial and tangential velocity components decrease outward from the jet axis, naturally leading to centrifugal instabilities. This, in turn, leads to the creation of large scale coherent structures at the periphery of the jet, particularly when it is in the vicinity of the free surface. The turbulent shear stresses exhibit anisotropic behavior, the largest always being in the plane passing through the jet axis. The change of TKE with S is not monotonic. It is maximum for S = 0.265, smallest

for S = 0.50, and has an intermediate value for S = 0.522. This is due to the occurrence of vortex breakdown and the resulting intensification of the turbulence within the jet prior to its exit from the nozzle.

SIMPLIFIED MICROMECHANICAL MODELS FOR ANALYSIS OF INTERFACE DEBONDING IN A FIBROUS COMPOSITE

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The objective of this study is to develop simplified micromechanical models to analyze the interface debonding between fiber and the matrix materials. Both analytical and simplified finite element models are used to predict the effective transverse elastic modules of fibrous composites with a partial interface crack based on the material properties of their constituents. The simplified finite element model uses springs in the connecting nodes between the fiber and matrix. A detailed finite element analysis, which is programmed using the MATLAB engineering software, is performed to check the accuracy of the simplified models. The simplified models yield accurate effective transverse elastic moduli of various composites with partial interface cracks when compared to the results obtained from detailed finite element analyses.

FACTORS AFFECTING THE IMPACT TOUGHNESS OF ULTRA LOW CARBON STEEL WELD METAL

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Master of Science in Mechanical Engineering-September 1996
Advisor: Alan G. Fox, Department of Mechanical Engineering
Second Reader: Terry McNelley, Department of Mechanical Engineering

The fundamental factors affecting the impact toughness of four gas metal are welds (GMAW) made on HSLA-100 base plate using a newly developed steel weld wire were studied. The weld metal analysis included chemistry, mechanical testing (hardiness, CVN/FATT), as well as optical, scanning and transmission electron microscopy. Studies of inclusion composition using energy dispersive x-ray (EDX), and electron energy loss spectroscopy (EELS) in the transmission electron microscope were also performed.

It was found that increasing oxygen content of the weld metal (due to increased oxygen in the shielding gas) led to increased non-metallic inclusion size and volume fraction; which in turn, led to both decreasing strength and toughness. The strength was lowered because increasing oxygen in the shielding gas led to increased 'consumption' of strengthening alloys such as carbon, manganese and silicon. The toughness was compromised by the increasing size and number of oxide inclusions as these provide sites for void formation and subsequent fracture.

THE INSTRUMENTATION DESIGN AND CONTROL OF A T63-A-700 GAS TURBINE ENGINE

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Master of Science in Mechanical Engineering-June 1996
Advisor: Knox T. Millsaps, Jr., Department of Mechanical Engineering

A T63-A-700 gas turbine engine has been instrumented to measure performance parameters. Pressure and temperature monitoring systems have been designed, fabricated, and installed to ensure accurate measurement of performance parameters. All measured parameters have been compared against predicted thermodynamic cycle analysis. Design and control of selected engine systems have been modified to incorporate more precise engine control and safety.

NUMERICAL ANALYSIS OF OSCILLATING FLOW ABOUT A CIRCULAR CYLINDER

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The numerical experiments, carried out through the use of a pressure-velocity coupled method to solve the Favre Averaged Navier-Stokes equations, on steady and sinusoidally oscillating flows at five different Keluegan-Carpenter numbers, and three periodicity levels are described. A second-order in time, second-order in space, second-level predictor-corrector finite difference scheme has been used. The solutions were solved by the CFD-ACE program from the CFD Research Corporation. The analysis has produced in-line force coefficients comparable to those obtained experimentally for sinusoidally-oscillating flows.

CONVECTIVE HEAT TRANSFER FROM A CYLINDER IN A STRONG ACOUSTIC FIELD

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Master of Science in Astronautical Engineering-December 1995
Advisor: Ashok Gopinath, Department of Mechanical Engineering
Oscar Biblarz, Department of Aeronautics and Astronautics

Experimental work was performed to study the convective heat transfer characteristics from a cylinder in a strong zero-mean oscillatory flow represented by an acoustic field. Two different flow regimes are discussed; that in which laminar, attached flow around the cylinder is present, and that in which instabilities, such as vortex shedding occur. The experiment utilizes a steady state measurement method. A transition from the laminar to the unstable regime was observed to occur at a streaming Reynolds number of approximately 240. Within the laminar regime, the transition from "intermediate" to "large" values of the streaming Reynolds number occurs at approximately 130. Heat transfer results for large values of the streaming Reynolds number in the laminar regime closely match the present theory (less than 13% error). Correlation's were developed to relate the heat transfer rate to the streaming Reynolds number in the unstable regime. This work would find application in the design of heat exchangers for a engine.

PRELIMINARY VIBRATION SURVEY OF A SUSPENDED FULL-SCALE 0H-6A HELICOPTER FROM O TO 45 HZ

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Efforts to establish a helicopter research program in structural dynamics at NPS were greatly enhanced when the U. S. Army donated two OH-6A light observation helicopters. One of the helicopters is reserved for ground vibration testing and dynamics research. Vibration measurements are extremely important in predicting and understanding an aircraft's dynamic behavior and durability. A comparison of a helicopter's natural frequencies and those frequencies transmitted to the airframe through the rotor system can alert the designer/evaluator to possible dynamic problems. This thesis establishes a baseline vibration test program on the OH-6A helicopter for future testing and comparison to analytic models. The goal of the research is to establish natural frequencies (eigenvalues), principal mode shapes (eigenvectors), and damping characteristics of the OH-6A and to compare these values to test and analytical data obtained from the McDonnell Douglas Helicopter Company.

PREDICTION OF HYDRODYNAMIC COEFFICIENTS UTILIZING GEOMETRIC CONSIDERATIONS

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A parametric study of a body of revolution is conducted utilizing existing semi-empirical methods for the calculation of hydrodynamic coefficients. The geometry of the body is analyzed in non-dimensional length and volume parameters. The effects of varying the nose, mid-body, and base fractions of the body on the hydrodynamic coefficients are generated and illustrated graphically. Equations for the hydrodynamic coefficients are then determined from the non-dimensional parameters. The results can be used to evaluate fundamental maneuvering characteristics early in the design phase.

ANALYSIS OF STEAM AND HYDRONIC COMPARTMENT HEATING SYSTEMS ABOARD U.S. COAST GUARD 140 FOOT WTGB CLASS CUTTERS

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The compartment heating system on the U.S. Coast Guard's Ice breaking Tug (WTGB) class cutter was studied to determine heat transfer performance characteristics of existing heat exchangers when used with circulating hot water vice steam. Characterizations such as Reynolds number vs. Colburn *j* factor plots, convection coefficients, overall coefficients, and Effectiveness-NTU relations were generated. Initial analysis with acknowledged conservative definitions of air side convection coefficients determined that the hydronic system provided on average seventy percent of the heat transfer capabilities available with the steam system. Improvements to the hydronic system were shown to increase heat exchanger performance parameters by an average of ten percent. It was notable that the added heat transfer available from steam is not due to a property of steam itself such as latent phase change effects, but is due solely to the increase in entering tube side temperature. Judging by heat transfer capabilities alone, with the described conservative assumptions on which these results are based, use of currently installed heat exchangers in a hydronic system is a viable option.

AN APPROACH TO USING TOTAL LIFE CYCLE COST AND TOTAL QUALITY MANAGEMENT IN PROJECT MANAGEMENT IN THE INDONESIAN NAVY

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Project management is very important to many industrial and governmental organizations. For governmental organizations, projects are vehicles for growth and improvement. In the Indonesian Navy for example, project management is needed to develop new warships, such as destroyers or submarines. The goal of project management is to ensure a high quality result.

Generally speaking, quality is defined as adherence to specifications and high quality is defined as exceeding those specifications. Not meeting the specifications is unacceptable quality. For a project like building a warship, the Total Life Cycle Cost can be considered primarily as a function of four things: design, construction, operation and maintenance. The selection of the design and the contractor are one time decisions and cannot be changed over the life of the

ship. In contrast, operation and maintenance are on-going management decisions, yet they are largely determined by the design selected and the quality of the contractor's work.

To have the lowest Total Life Cycle Cost, the right design and the right contractor must be selected. This thesis develops a Design Review Checklist and a Contractor Review Checklist that can be used in reviewing the contractor's design and the contractor's quality management capabilities.

RESISTIVITY MEASUREMENT BY EDDY CURRENT METHODS FOR REAL-TIME MONITORING OF AGE HARDENING IN HEAT TREATABLE ALLOYS

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In this research, the design of an eddy current sensor system that continuously monitors age hardening during aging of heat treatable alloys was modified to allow for operation at temperatures up to 595°C. With two eddy current coils in an impedance bridge circuit, eddy currents are generated in a pure aluminum reference sample standard and an age hardenable test sample. The difference in the resistivity of the aging test sample relative to the reference sample results in a bridge unbalance voltage, ΔV_{BCA}, which is continuously measured by a multimeter. Also, calibration procedures were developed to allow conversion of the values of ΔV_{BCA} to a resistivity difference, $\Delta\rho = \rho_{test} - \rho_{ref}$, between the test and reference samples. These calibration curves were generated by measuring ΔV_{BCA} at various temperatures for six test samples standards of known resistivity. The resistivity of the aging sample is determined by adding the known resistivity value for pure aluminum to $\Delta\rho$. Real-time monitoring of an aging alloy's resistivity may allow heat treaters to integrate this monitoring system with a control system to achieve "intelligent heat treating".

FREQUENCY DOMAIN STRUCTURAL IDENTIFICATION

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The Structural Synthesis Transformation is used to conduct structural system identification in the frequency domain. For spatially complete cases where each of the frequency response functions at every degree of freedom of each of the coordinates of the modeled system are available it is shown that the theory exactly identifies all modeling errors. For spatially incomplete cases where the frequency response functions are available only at a proper subset of the degrees of freedom of the finite element model, single mode solutions are computed over intervals about the modes of the experimental system using matrices and complex valued line integrals. Methods of forming multiple mode solutions from the single mode solutions are explored.

THE EFFECT OF A NOVEL COATING TECHNIQUE ON FILMWISE AND DROPWISE CONDENSATION OF STEAM ON HORIZONTAL TUBES

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Steam condensation heat transfer on smooth horizontal tubes and on a Korodense horizontal tube was experimentally studied at a atmospheric pressure and at vacuum. The overall heat transfer coefficient was measured and the outside heat transfer coefficient was determined from the modified Wilson Plot Technique. A hydrophobic coating of a self-

assembling monolayer (SAM) with a composition of $HS(CH_2)_{15}CH_3$ promoted excellent dropwise condensation (DWC) on tubes. Coexisting strips with varying widths of filmwise condensation (FWC) and DWC, but at a constant area ratio of 50%, were also investigated.

Smooth tubes coated with the hydrophobic SAM produced DWC heat transfer coefficients of up to 10 times that of FWC at atmospheric conditions and up to 4 times at vacuum. The Korodense tube coated with the hydrophobic SAM produced heat transfer coefficients of up to about 3 times that of FWC at atmospheric conditions and up to about 2.5 times at vacuum. Data with coexisting strips of FWC and DWC showed that the heat transfer performance was influenced by the width of strips, size of drops, condensate turbulence and loss of drop sweeping action, indicating an optimum combination of strips may exist.

DEVELOPMENT AND ASSESSMENT OF A SHIP MANEUVERING SIMULATION MODEL

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A nonlinear maneuvering model based on ship geometric and mass properties is developed. The model can be utilized to evaluate maneuvering performance early in the design phase. This model is also used in this thesis as a benchmark in order to evaluate the accuracy of the simpler Nomoto's model. The latter is faster to simulate and is ideally suited for visual simulation studies. Results comparing the relative accuracy and speed of implementation of the two models are presented for different inputs and geometric properties. An improvement to Nomoto's model is suggested which greatly increases accuracy while maintaining high speed of real time implementation. Furthermore, a series of parametric studies is performed in order to evaluate the sensitivity of fundamental maneuvering properties in terms of basic ship geometric quantities.

MODELING OF CRACK INITIATION AND GROWTH IN SOLID ROCKET PROPELLANTS USING MACROMECHANICS AND MICROMECHANICS THEORIES

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Modeling and simulation of crack initiation and propagation in solid rocket propellant materials were conducted using both the macromechanics approach and the micromacromechanics approach. Due to their composition, the solid rocket propellant can be construed as particle reinforced composites.

The macromechanics approach entailed a numerical simulation of a finite element model to predict the crack behavior based on the damage initiation, growth, and local saturation. Its results were then compared to the experimental data. In the simulation, it was assumed that a crack forms when a damage is saturated in a localized zone. The results from the simulation were quite comparable to the experimental results, validating the method of predicting crack initiation, growth, and arrest using the concept of damage growth and saturation.

The second approach involved using a simplified micromechanical model and the damage mechanics being applied at the micromechanics level and the finite element analysis being done subsequently at the macromechanics level. In using this approach, the damage modes such as matrix cracking, interface debonding and particle cracking were explainable in an explicit, fundamental manner. Several simulations were conducted using this approach including the cases of non-uniform particle distribution. The predicted results compared well with the experimental data.

SIMULATION OF SMALL ROBOTIC VEHICLE PERFORMANCE DURING UXO GATHERING OPERATIONS USING DISCRETE EVENT CONTROL

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The subject of minefield clearance has received much attention in the last few years due to its necessity during modern war fighting, and its unavoidable inherent dangers. Clearing the battlefield of Unexploded Ordnance (UXO) is a formidable task that presently requires the risk of human life. Future strategy calls for the use of a fleet of small, inexpensive, but very capable robots to clear the battlefield of all Unexploded Ordnance. The Navy's Explosive Ordnance Disposal Technical Center has developed a "BUGS" Basic UXO Gathering System in order to examine such strategy. In support of this effort, simulations are being conducted to examine the effects of navigation, control schemes, and terrain characteristics on battlefield clearance operations.

EXPERIMENTAL STUDY OF INELASTIC STRESS CONCENTRATION AROUND A CIRCULAR NOTCH

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Experiments were conducted to determine whether energy-density relations can be used to predict elastic-plastic stresses and strains near a circular notch for 7075-T6 aluminum alloys and ARALL 4 composites. The loading conditions were tension and four-point bending. Glinka and Neuber have developed relations that predict local inelastic strain response based on the stress-strain solution for small plastic zone sizes. It has been shown that these relations are appropriate for simple tension and in-plane bending, where stress and strain are uniform through the thickness. This study investigates the application of the Glinka and Neuber relations to samples where stress/strain is not constant through the thickness. Non constant stresses/strains are the result of out-of-plane bending and laminate characteristics.

AUTONOMOUS CONTROL OF UNDERWATER VEHICLES AND LOCAL AREA MANEUVERING

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The major thrust of this work is the development and demonstration of new capabilities for the use of small autonomous vehicles in mine countermeasure applications. Key to the new capabilities lies in an open architecture tri-level software structure for hybrid control, of which this work is the first validated implementation. The two upper levels run asynchronously in computing logical operations based on numerical decision making, while the lowest, the Execution Level, runs synchronously to maintain stability of vehicle motion. The top (Strategic) Level of control uses Prolog as a rule based language for the specification of the discrete event system (DES) aspects of the mission. Multiple servo controllers are coordinated by the middle (Tactical) Level software in performing the mission, while the Execution Level controllers guarantee robust motion stability through multiple sliding modes.

This hardware/software arrangement provides the ability to operate a hybrid (mixed discrete state/continuous state) controller for semi-autonomous and autonomous vehicles in which the missions imply multiple task robot behavior. This work has defined and developed a set of vehicle "primitives", that are a set of stable modular control functions unique to a given vehicle's capabilities. It is demonstrated how these can easily be combined using rules to specify as simple, or as complex, a mission as desired. Completion of a mission is guaranteed through a "complete plan" including time traps and error recovery procedures. Experimental results are given illustrating the performance attained.

A particular case of the technique developed has resulted in a method to navigate an AUV in a local area (around a mine-like object) using a profiling sonar sensor for position information derived from underwater feature detection. Since sonar image feature extraction is necessarily time consuming, a dynamic model of the vehicle response is used for control between position updates. A structured formulation of this control/navigation method is presented followed by results from in water implementation using the NPS Phoenix vehicle and the tri-level software structure described above.

BOUNDARY CURVATURE EFFECTS ON GAS BUBBLE OSCILLATIONS IN UNDERWATER EXPLOSION

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The oscillation of a gas bubble produced as a result of underwater explosion could cause the severe whipping damage on nearby marine vehicle. The effects of rigid boundary curvatures to explosion gas bubble oscillation behavior in underwater were investigated. The analyses were conducted using a multimaterial Lagrangian-Eulerian finite element code, MSC/DYTRAN. The incident shock wave pressure, bubble pulse pressure, gas bubble radius and period were calculated for the case of detonation of a charge near the curved rigid boundary. The results were compared for the case of free field bubble oscillations.

DISCRETE ASYNCHRONOUS KALMAN FILTERING OF NAVIGATION DATA FOR THE PHOENIX AUTONOMOUS UNDERWATER VEHICLE

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The Phoenix Autonomous Underwater Vehicle must be able to accurately determine its position at all times. This requires: 1) GPS and differential GPS for surface navigation, 2) short baseline sonar ranging system for submerged navigation, and 3) mathematical modeling of position.

This thesis describes a method of Kalman filtering to merge the GPS, differential GPS, short baseline sonar ranging, and the mathematical model to produce a single state vector of vehicle position and ocean currents. The filter operates in the extended mode for processing the non-linear sonar ranges, and in normal mode for the linear GPS/DGPS data. This required installation of a GPS system and the determination of the different variances and errors between these systems.

Phoenix now has a real time method of position determination using either position measuring system separately or combined. The results of this work have been validated by real world testing of the vehicle at sea, where position estimates accurate to within several meters were obtained.

A CHARACTERIZATION OF THE MAXIMUM BENDING STRESS OF THE SLICE HULL IN RANDOM SEAS

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A study of the effects of speed, heading and sea state on the maximum longitudinal bending stress of the SLICE Advanced Technology Demonstrator is presented. Strip Theory is applied to a model of the SLICE hull. The hull is modeled using data from a current design and with ship loading weight information for ferry operations. Stress results are based on conventional beam theory applied to the hull girder. Bending moment distributions are presented for random, fully-developed, unidirectional seas. The maximum expected bending stress is calculated for varying sea states, ship speeds, and wave directions. Operability of the SLICE based on limiting material stress is evaluated for sea states through sea state 6. The results of this study indicate that increased stiffening of the hull could be considered in the vicinity just aft of the forward pods.

EXPLORATION OF THE DAMAGE STABILITY CHARACTERISTICS OF THE TRIMARAN SURFACE COMBATANT

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The new world situation and important changes in the military policy of the United States have made it necessary to find new alternatives for warships. Affordability, high performance and excellent seakeeping, combined with a high degree of survivability, are essentials for the new century. The trimaran hull form holds promise in fulfilling future needs of Navy combatants. This thesis attempts to make an evaluation of the response of the trimaran hull under nine (9) different cases of damage stability. The specifications of the multihull correspond to a "4600 Tonnes Trimaran Warship" in the process of being evaluated by NAVSEA. Many analysis problems were encountered because of the unusual type of tumble-home hull and the "wavepiecer" shape of the bow. The results show an overall good response to a damage stability analysis. The critical case, unsurprisingly, has been found to be when one side hull is flooded and the tanks in the opposite hull are completely empty. Important conclusions and data were obtained, and future research areas are identified.

PARAMETRICS OF SUBMARINE DYNAMIC STABILITY IN THE VERTICAL PLANE

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The problem of dynamic stability of submersible vehicles in the dive plane is examined utilizing bifurcation techniques. The primary mechanism of loss of stability is identified in the form of generic Hopf bifurcations to periodic solutions. Stability of the resulting limit cycles is established using center manifold approximations and integral averaging. The hydrodynamic coefficients are calculated using existing semi-empirical methods. Parametric studies are performed with varying vehicle geometric properties. The methods described in this work could suggest ways to enlarge the submerged operational envelope of a vehicle early in the design phase.

DESIGN AND ANALYSIS OF A GAS TURBINE TEST FACILITY AIR SYSTEM

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A gas turbine test facility air system has been designed to meet specified design objectives. An analytical evaluation was performed on the air system design to verify that these design objectives were achieved. A key element of the air system is an exhaust eductor which was included in the design to provide secondary cooling air flow through the engine test cell. Two analytical models were developed to evaluate exhaust eductor performance. A one-dimensional, incompressible eductor model was developed that predicts the basic eductor performance parameters including the amount of secondary air flow drawn through the engine test cell for varying eductor configurations. This model also predicts overall air system performance parameters. An eductor computational fluid dynamics analytical model was developed that provides a more detailed analysis of the flow in the eductor.

AN INVESTIGATION OF THE EFFECTS OF SECONDARY PROCESSING ON THE FRACTURE PROPERTIES OF A SiCp-6XXX A1 COMPOSITE

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Discontinuous reinforced aluminum (DRA) composites are attractive as structural materials because of their desirable stiffness and strength to weight ratios and relative ease of manufacture. However, they typically display low tensile ductility and fracture toughness. In this work, the impact of postfabrication deformation processing and heat treatment on the fracture properties of a 17.5 vol. % SiCp reinforced Al 6092 matrix composite is investigated. Process temperature, total strain and strain rate during extrusion were varied in order to explore the feasibility of obtaining Particle Stimulated Nucleation (PSN) of recrystallization during processing, with the goal of refining the matrix grain size. Additionally, various combinations of solution and aging treatments were investigated with the aim of obtaining a number of stable matrix microstructural conditions with varying levels of composite strength and fracture toughness. A preliminary investigation of fracture mechanisms and their dependence on the matrix aging state has also been carried out using optical and scanning electron microscopy (SEM) and differential scanning calorimetry (DSC), and is reported here.

DESIGN OF AN ARTICULATED MANIPULATOR FOR ENHANCED DEXTERITY IN MINIMALLY INVASIVE SURGERY

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A current limitation in minimally invasive surgical (MIS) procedures is the lack of an articulated mechanism which will provide dexterity inside the torso while supporting a surgical tool. The tool could be a pair of scissors or an optical device such as a camera, or both. To overcome this limitation we have designed an Articulated Manipulator for Minimally Invasive Surgery (AMMIS). The AMMIS is expected to provide surgeons with improved dexterity during MIS procedures and be ideally suited for tele-surgery. This design may also be used in non-medical applications such as aviation maintenance, and engine inspection.

THEORETICAL AND EXPERIMENTAL INVESTIGATION OF THE RESPONSE OF A ROTOR ACCELERATING THROUGH CRITICAL SPEED

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The rotordynamic response of an imbalanced rotor accelerating through its first lateral bending critical speed was investigated both analytically and experimentally. A two degree-of-freedom lumped mass, damping and stiffness model was developed to simulate the response of a simply supported, single disk rotor during both acceleration and deceleration. The equations of motion were then solved numerically. The computer model was used to determine the effect of acceleration rate, asymmetric stiffness and damping, and acceleration scheduling on the maximum amplitude of the response. Experimental data for a simply supported, single disk rotor accelerating at different rates were compared with the computer model. Increased acceleration rates and damping reduce the magnitude of the response. Asymmetric stiffness and acceleration scheduling can also be used advantageously to reduce the maximum amplitude of the response.

EXPERIMENTAL EVALUATION OF A LOW COST ACOUSTIC COMMUNICATION SYSTEM FOR AUVs

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Advisor: Anthony J. Healey, Department of Mechanical Engineering

As the Navy has refocused its goals towards littoral warfare, mine countermeasures have become an area of special interest. The Naval Postgraduate School is developing an autonomous underwater vehicle to map shallow water minefields—a vital role in the Navy's overall plan for mine countermeasures. A key feature of the vehicle is its low cost, and to this end it uses a commercially available system called "DiveTracker" for precise acoustic navigation and communication. This research experimentally evaluated the reliability of the DiveTracker communication system in conditions approximating those for which the vehicle is designed. It was concluded that highly reliable communication of short commands will be restricted to relatively short separation distances between nodes. The very shallow water acoustic channel is highly variant in both signal attenuation and background noise levels. The maximum range is limited by the background noise while the probability of correct message reception depends on the received signal ratio. Initial data indicates that the low cost unit under development cannot communicate beyond 500 meters with a probability of a single roundtrip success greater than 34 percent. Several options are available for its improvement.

OPTIMAL SOLUTION SELECTION FOR SENSITIVITY-BASED FINITE ELEMENT MODEL UPDATING AND STRUCTURAL DAMAGE DETECTION

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The finite element model has become the standard way in which complex structural systems are modeled, analyzed, and the effects of loading simulated. A new method is developed for comparing the finite element stimulation to experimental data, so the model can be validated, which is a critical step before a model can be used to simulate the system. An optimization process for finite element structural dynamic models utilizing sensitivity based updating is applied to the model updating and damage detection problems. Candidate solutions are generated for the comparison of experimental frequencies to analytical frequencies, with mode shape comparison used as the selection criteria for the

optimal solution. The method is applied to spatially complete simulations and to spatially incomplete experimental data which includes the model validation of a simple airplane model, and the damage localization in composite and steel beams with known installed damage.

A NEW KINEMATIC MODEL FOR THE STUDY OF THE ROLE OF THE ANTERIOR CRUCIATE LIGAMENT (ACL) IN HUMAN KNEE MOTION

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A six degree of freedom model was utilized to continuously measure the motions of loaded cadaveric human knees with unconstrained motion at the tibiofemoral joint through a range of motion from zero to 110 degrees of flexion. Several conditions were studied. Loading conditions were varied to simulate the natural body forces (i.e., the normal condition) and quadriceps-deficient condition. The range of motion in which the anterior cruciate ligament (ACL) is the primary restraint to anterior tibial translation was determined. The effect of ACL insufficiency on the kinematics of the human knee was investigated by comparing the kinematics of the knee specimens in the intact state with the kinematics obtained after the ACL was surgically severed. To simplify the complex kinematics of a six degree of freedom model, the motion of the instant center of the tibiofemoral joint for each specimen was estimated using the femoral transepicondylar pin reference point. The estimated motion of the instant center of the knees in the intact state and ACL deficient state and compared to empirical observations. The importance of the motion of the instant center was then determined in pathologic knee motion. Finally, the effect of total knee replacement on kinematics was investigated.

FLUID-INTERACTION AND CAVITATION EFFECTS ON A SURFACE SHIP MODEL DUE TO AN UNDERWATER EXPLOSION

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A surface ship subjected to an underwater explosion is exposed to shock waves over a short period of time which can vary in magnitude based on charge type, size, and location. The energy of those waves impinging upon the hull is transmitted throughout the ship's structure and vital equipment. The dynamics of the shock waves also influence the fluid surrounding the outer hull of the ship, creating an area of cavitating fluid. The combination of the shock waves, bubble pulsations, and cavitating fluid induce shipwide vibrations on hull supports and mission essential equipment which may become inoperative. In view of congressional requirements for new ship designs and systems to be shock tested, this thesis investigates the modeling of a preliminary design (Flight I) of the Arleigh Burke Destroyer (DDG 51) exposed to an underwater explosion. The effects of cavitation on one and two dimensional models is explored to determine if cavitation effects are substantially important to a three dimensional ship model. Validation of modeling underwater explosion effects upon a ship model can provide potential insight and savings in cost for future live fire testing and evaluation of the Flight IIA (DDG 79) design of the Arleigh Burke Destroyer.

AN INVESTIGATION OF THE RESISTANCE PROPERTIES OF A MODERN TRIMARAN COMBATANT SHIP BASED ON TAYLOR STANDARD SERIES AND SERIES 64

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The resistance properties and effective horsepower requirements for a trimaran being considered for SC-21 (Surface Combatant for the 21st century) are investigated. The effects on EHP due to increased side hull displacement are analyzed. Residual-resistance coefficients are obtained for side hull displacements up to 5% of the center hull's displacement. Coefficients are based on the Taylor Standard Series and Series 64 data. The effects of interference on effective horsepower requirements are discussed. The potential use of Reynolds-averaged Navier-Stokes (RANS) code is presented.

ACOUSTIC UNDERWATER NAVIGATION OF THE PHOENIX AUTONOMOUS UNDERWATER VEHICLE USING THE DIVETRACKER SYSTEM

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Master of Science in Mechanical Engineering-March 1996
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Autonomous Underwater Vehicles (AUVs) require a navigation system in order to conduct useful functions. This research was an experimental investigation of the commercial DiveTracker underwater acoustic navigation system used onboard the NPS Phoenix AUV. Tests conducted with the DiveTracker system proved that the system could be used successfully in AUV navigation while submerged and revealed that more precise positioning could be obtained through postconditioning of the DiveTracker output range, rather than prefiltering.

INTEGRATED SYSTEM DAMPING AND ISOLATION OF A THREE DIMENSIONAL STRUCTURE

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Controlling the vibratory response of a mechanical system is of key importance in most modern engineering designs. Constrained viscoelastic layered damping of vibrating elements is one method that can be used for vibration reduction. This thesis deals with an integrated system damping and excitation source isolation scheme for reducing the vibration signature of a three dimensional structure. Use of a validated finite element model of the system to predict system dynamic behavior proved to be an effective method in the design of the constrained viscoelastic layered damping treatment. Direct frequency response analysis was performed on the structure with the damping treatment applied and excitation source isolated. Experiments were also performed on the structure without the damping treatment to provide reference data for comparison purposes.

ASSESSMENT OF GRAIN REFINEMENT BY MICROTEXTURE ANALYSIS IN THERMOMECHANICALLY PROCESSED AL 2519 ALLOY

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The first part of this study involved determining the mechanism by which elevated-temperature deformation occurred for selected tensile specimens from previous research on thermomechanically processed Al 2519 alloy. Microtexture information in the form of discrete pole figures indicated that the most highly superplastic material had completely recrystallized and deformed via grain boundary sliding, whereas material that did not display superplastic behavior deformed via slip. The second part of the study was designed to achieve further refinement of the microstructure of Al 2519 using the particle stimulated nucleation (PSN) model as a guide. Using the overaging parameters of the thermomechanical process (TMP) that had yielded the greatest elongation in previous work, additional material was processed but with varying final total processing strain. The resulting material was analyzed using backscatter electron (BSE) microscopy methods to evaluate the effect of total processing strain on the average grain size. The smallest true volume grain size was associated with the material with the highest total processing strain.

PROPELLANT FEED CONTROL FOR ION ENGINES

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Second Reader: Knox T. Millsaps, Jr., Department of Mechanical Engineering

An overview of space electric propulsion (SEP) is presented. Methods of throttling the power levels of electrostatic and electromagnetic thrusters are discussed. Particular attention is given to the concept of thermally-throttling propellant flow using the temperature-viscosity characteristics of xenon gas. The thermo properties of xenon gas as a function of temperature are determined, and the flow regimes of the propellant at the mass flow rates of interest are studied. The propellant flow is presented separately as Fanno flow and as Rayleigh flow, and then those combined effects are considered. A method for predicting the performance of thermally-throttled systems is presented. Uncertainties in modeling real-world thermal throttling systems are discussed. The possible use of thermal throttling characteristics as a means of propellant pressure regulation is also examined.

HEAT TRANSFER STUDIES AND FLOW VISUALIZATION OF A RECTANGULAR CHANNEL WITH AN OFFSET-PLATE-FIN ARRAY

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The heat transfer characteristics and flow visualization of a 10X scale version of internal offset-fin plate array within the liquid flow-through module for electronics cooling were investigated experimentally using water as a cooling fluid. By varying power input settings and coolant flow rates, the heat transfer effects from the plate array to the coolant water was investigated. Additionally thermochromic liquid crystals were spray-painted onto the plate to determine the temperature distribution within the heat transfer surface, as compared to the readings from the attached thermocouples. Finally a flow visualization using the dye-injection technique was to study the flow patterns of the coolant through the fin array.

RECOVERY FACTORS IN ZERO-MEAN INTERNAL OSCILLATORY FLOWS

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High speed oscillatory flows, like high speed mean flows, are capable of inducing time-average heat transfer effects. This research involves the analytical solution of a model problem of zero-mean internal oscillatory flow, which arises from a high-intensity resonant standing acoustic wave set up across the ends of two parallel plates. The compressible form of the Navier-Stokes equations are solved, along with the equations of continuity, energy, and state, using perturbation solution and complex variable methods. MAPLE, a symbolic mathematical software tool, is utilized to find the time-averaged portion of the temperature distribution between the plates. The final heat transfer results are presented in terms of suitably defined recovery factors. The analysis is performed for varying gap widths between the plates using air as the host fluid. This work provides the fundamental explanation of the phenomenon responsible for the thermoacoustic refrigerating effect as well as an analytical basis for determining the optimum gap width between the plates of the stack in a thermoacoustic refrigerator.

VORTEX BREAKDOWN AT Re= 130,000

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Vortex breakdown is an impressive structural change in the core of a vortex, generally liable to occur in any flow characterized by longitudinal vortices. The previous mathematical and experimental studies dealt with laminar breakdowns at Reynolds numbers less than about 10,000. The present investigation deals with a relatively high Reynolds number of 130,000 in a non-cavitating swirling flow at which a new conical-type turbulent vortex breakdown occurs. Axial and swirl velocities along the test pipe are measured with a Laser Doppler Velocimeter and used to interpret the role of vortex breakdown in changing a jet-like flow into a wake-like swirling flow with a larger core.

STUDIES ON SUBMARINE CONTROL FOR PERISCOPE DEPTH OPERATIONS

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Mechanical Engineer-September 1996
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Requirements for submarine periscope depth operations have been increased by integration with carrier battle groups, littoral operations, and contributions to joint surveillance. Improved periscope depth performance is therefore imperative. Submarine control personnel rely on a large number of analog gauges and indications. An integrated digital display system could enhance the ergonomics of the human control interface and display additional parameters. This thesis investigates the required feedbacks for robust automatic depth control at periscope depth, and thus indirectly determines the additional parameters desired for an integrated display.

A model of vertical plane submarine dynamics is coupled with first and second order wave force solutions for a particular submarine full form. Sliding mode control and several schemes of state feedback are used for automatic control. Head and beam seas at sea states three and four are investigated. The automatic control effectiveness provides insight into the indications used by the ship's control party in operations at periscope depth. One possible display

system is proposed, with several additional enhancements to improve ship's safety, reduce operator fatigue, and enable accurate reconstruction of the events leading to a loss of depth control.

ASSESSMENT OF SHALLOW WATER NEAR SURFACE RESPONSE OF SUBMERSIBLE VEHICLES

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Vertical plane response of submersible vehicles in the proximity of a free surface in both deep and shallow waters is evaluated using a potential flow, strip theory solver. Three criteria, namely periscope submergence, sail broaching, and collision are used to quantify the response. These criteria combined with the vehicle's response amplitude operators in regular sinusoidal waves along with a statistical description of the seaway lead to an assessment of an overall operability index for the vehicle. The operability index is calculated within a given range for sea states and sea directions and for various vehicle speeds and operating depths. The results indicate that a certain combination of depth and speed can lead to a significant improvement in vehicle operations.

BOILING OF HIGHLY WETTING LIQUIDS IN OSCILLATORY FLOW

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In the present study, boiling of highly wetting dielectric fluid has been investigated in an oscillating fluid environment. A piston is designed to create oscillations in the fluid and over the heated platinum wire. Because of their low surface tension, these liquids require very high superheat to initiate nucleate boiling. It is expected that the amount of necessary temperature overshoot for the onset of nucleate boiling, can be decreased with oscillation in the fluid. The oscillation can remove the bubbles, which are forming in the nucleation sites as soon as they start growing on the outer surface. This increases efficiency of nucleation sites, which are very scarce.

All of the oscillation amplitudes and frequencies, tested here, changed the boiling curve of highly wetting dielectric fluid, so that the apparent temperature overshoot has decreased. Remarkably at some oscillation amplitude and frequencies the superheat is almost vanished. The effects of the amplitudes and frequencies on the boiling curve varied because of the present bubble size and growth rate, which depend on the size of the nucleation sites.

NUMERICAL AND EXPERIMENTAL STUDY OF FAILURE OF THE HUMAN PROXIMAL FEMUR

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Static and dynamic experiments were conducted to study the failure loads and fracture patterns of human proximal femur bones, that are intact and core drilled. This was done to assist orthopedic surgeons to better understand the effects of core drilling into the femoral head to remove osteonecrosis. Unlike previous studies, where only static tests were conducted, dynamic tests were preformed to better simulate a lateral fall. A Finite Element Analysis (FEA) was also completed to understand stress distributions in the proximal femur when subjected to static and dynamic loads. Previous FEA models of the femur analyzed static loads only with just a core drilled hole at the lesser trochanter. This FEA model examines various sizes of hole diameters and locations on the greater trochanter as well as having the model loaded statically and dynamically.

DESIGN AND METHOD FOR THE EVALUATION OF THE COKING RESISTANCE OF SWIRL PLATES OF THE E-2C AIRCRAFT FUEL NOZZLES

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The extensive coking observed on the swirl plates of the fuel nozzles of the E-2C HAWKEYE aircraft is the initiative of this investigation. A testing rig reproducing the shut down procedure of the engine was designed and a method for the evaluation of the resistance in coking for different types of swirl plates is presented. The method is based on measurements of weight increase and holes closure, and on microscopic examination. It can be applied to the evaluation of any suggested modification of swirl plates in the future and provides the Navy with a reliable easy to use and modify experimental set-up able to produce comparative data. Results for two different types of swirl plates with different surface finish are presented, together with conclusions and comments arising from the experimental results and the design process. Recommendations for future search objectives relative to the problem are also presented.

MAGNETIC INDUCTIVE SENSOR APPLICATIONS FOR ROBOTIC ORDNANCE DETECTION AND RECOVERY

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The use of robotic vehicles to detect and remove unexploded ordnance (UXO) from battlefields and training ranges is currently being explored by the Naval Explosive Ordnance Disposal Technical Division, Indian Head, Maryland. In support of this effort, research was conducted in the characterization and use of small, commercially available magnetic inductance sensors to detect a variety of common U.S. submunitions. Sensor test bed mounting on a small wheeled vehicle with a sweep device allowed for dynamic testing against submunitions under laboratory and field conditions.

A COMPARATIVE STUDY INTO THE COKING RESISTIVITY OF SWIRLPLATES WITH VARIOUS SURFACE FINISHES

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Gas turbine nozzle swirlplates used in the T56-A-427 engines of the E-2C Hawkeye aircraft were tested for their resistivity to fuel deposit formations, or 'coking'. The coking occurred after the engines were shut down due to the fuel trapped in the line and temperature ranges present at the nozzle tip. As the coke built up, the holes in the swirlplates clogged and the aircraft required intensive servicing. The search for alternative solutions led to the possibility of using swirlplates that have been polished or coated in an attempt to reduce the coking rates. Several swirlplate surface finishes were investigated.

FINITE ELEMENT MODELING OF SANDWICH COMPOSITE STRUCTURES SUBJECT TO LOW VELOCITY IMPACT AND DELAMINATION

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Two common concerns in the use of sandwich composite construction are the effects of low velocity impact and delamination upon structural failure. Finite element analysis of these events can provide a comprehensive time history of the resulting stress, strain, and displacement as all points in a structure. The purpose of this research is to develop a fem model of a sandwich composite and use this model to analyze the dynamic response of various sandwich configurations subject to low velocity impact. In particular, strain vs time history, failure location mode, and the influence of an existing delamination are investigated.

AN OPTIMIZATION TECHNIQUE USING THE FINITE ELEMENT METHOD AND ORTHOGONAL ARRAYS

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The objective of this research was to develop an optimization technique that can be used interactively by design engineers to approach an optimal design with minimal computational effort. The technique can be applied to both continuous and discrete values of design variables. A large number of design variables can be also considered.

In order to meet the objective, an optimization procedure was developed by coupling the finite element analysis (FEA) to the orthogonal array experimentation technique, because FEA is a common analysis tool for design engineers. From the results of the FEA and an orthogonal array, an average Jacobian matrix was constructed that showed the average overall sensitivity of the design variables. These sensitivities were then used to optimize the design parameters. The process could then be repeated at the discretion of the engineer until a satisfactory design is obtained. In general, the designer can predict and control the number of FEA calculations before an optimization process so that one can plan a budget and time for an optimal design.

Some examples of structural optimization with truss and frame structures with continuous and discrete values of design variables were studied using the technique developed in this paper. Their optimal solutions were found with small numbers of iterations.

EXPERIMENTAL INVESTIGATION OF FLOW CONTROL BY MEANS OF AIRFOIL FLAPPING

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Flapping airfoils generate thrust-producing jet-like wakes. It therefore is the objective of this investigation to explore whether this feature can be used for effective flow control. To this end, the flow characteristics of flapping airfoils are first explored in a water tunnel experiment, using dye flow visualization and laser-Doppler velocimeter. The effect of airfoil flapping frequency and amplitude of oscillation and of flow velocity on the wake flow characteristics are determined. This is followed by a second water tunnel experiment, where a small flapping airfoil is mounted in and near the

separated flow region caused by the flow over a backward-facing step. The effect of airfoil size, location, frequency, and amplitude of oscillation on the separated flow region is again determined by means of laser-Doppler velocimeter. It is found that the reattachment length of the separated flow region can be reduced by as much as 70%.

ANALYSIS OF THE DIVETRACKER ACOUSTICAL NAVIGATION SYSTEM FOR THE NPS AUV

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Autonomous Underwater Vehicles (AUVs) require an accurate navigation system for operating in mine fields located in the near surf zone very shallow water. This research project examined the precision, performance characteristics, and reliability of a low cost, commercially produced, acoustical navigation system called "DiveTracker". The DiveTracker acoustical navigation system provides both an acoustical short baseline operator and the AUV with position data on a 1 hertz update rate. Experiments conducted on the DiveTracker system included static and dynamic tests which examined the system's ability to accurately measure distances and track a moving AUV under water.

THE APPLICATION OF VIDEOGRAMMETRY IN THE STRUCTURAL TESTING OF SPACECRAFT

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This thesis will study the application of video photogrammetry in satellites and space systems. Industrial photogrammetry provides an extremely accurate and versatile means for non-contact, three-dimensional digitizing of a sample of points on an object of interest. Photogrammetry is non-invasive, because it measures photographic negatives of the object, not the object itself. Its flexibility and versatility are derived from photogrammetry's ability to view the object from many different angles in almost any test configuration. Using the process of optical triangulation the two-dimensional images from the different views are transformed into three-dimensional coordinate data. This data is then analyzed to provide the desired results. Tests were conducted during an experience tour at TRW Space and Electronics Division, Redondo Beach, California. The applications include a K-Biaxal unit rotation and orthogonality test, a boom stiffness test. The analysis will address the accuracy, versatility and adaptability, speed, and reliability of videogrammetry and compare it to other current test procedures such as linear variable differential transformers (LVDT) and strain gages.

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